STATE OF CONNECTICUT.

NINTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1896.

PT. I pp. 1-84
Pt. II pp. 85-204
Pt. III pp. 205-292

Printed by Order of the General Assembly.

MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
1897.

Publications of the Station.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications should be addressed to

Storrs Agricultural
Experiment Station,
Tolland County. Storrs, Conn.

CONTENTS.

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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural College. The chemical and other more abstract research is carried out at Wesleyan University, Middletown, where the Director may be addressed.

Report of the Executive Committee.

To His Excellency Lorrin A. Cooke,
Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly approved March 19, 1895, relating to the publication of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Ninth Annual Report of that Station, namely, that for the year 1896.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year. We are confident that the funds have been wisely expended and that the work accomplished is such as will result in great benefit to our agricultural and other interests.

Mr. Chas. D. Woods, Vice-Director of the Station, resigned his position July 1, 1896, to accept that of Professor of Agriculture and Director of the Experiment Station of the Maine State College. Professor Woods has been connected with the Storrs Station since a short time after its organization. His services have been most valuable and highly appreciated. While the Executive Committee share with the other friends of experiment stations in Connecticut the sense of the loss to our State, they are at the same time glad that the field of labor to which he has been called should be one of so large usefulness and honor.

Respectfully submitted,

T. S. GOLD,
J. M. HUBBARD,
B. F. KOONS,
Executive Committee.

Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30, 1896.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.

United States Treasury,	$7,500 00

EXPENDITURES.

Salaries,	$4,844 96
Labor,	482 09
Publications,	183 20
Postage and stationery,	331 28
Freight and express,	111 50
Heat, light, and water,	352 97
Chemical supplies,	367 42
Seeds, plants, and sundry supplies,	53 38
Fertilizers,	105 48
Feeding stuffs,	122 66
Tools, implements, and machinery,	22 85
Furniture and fixtures,	87 83
Live stock,	179 12
Traveling expenses,	164 46
Contingent expenses,	10 00
Building and repairs,	80 80
Total,	$7,500 00

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS—RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Sale of produce,	52 10
Miscellaneous receipts, including sale of apparatus,	762 49
Total,	$2,614 59

EXPENDITURES.

Salaries,	$902 38
Labor,	211 11
Chemical supplies,	115 77
Bacteriological investigations,	400 00
Seeds, plants, and sundry supplies,	233 76
Fertilizers,	88 89
Furniture and fixtures,	22 37
Scientific apparatus,	640 31
Total,	$2,614 59

HENRY C. MILES, *Treasurer.*

Report of the Director for the Year 1896.

The principal subjects of inquiry and lines followed during the past year may be concisely stated as follows:

METEOROLOGICAL OBSERVATIONS.

These have been continued during the past year, as previously, at Storrs, where records have been made of temperature, barometric pressure, wind velocity, humidity, rainfall, and snowfall. In addition, records of rainfall during the growing season have been made in other places in the State by farmers who have coöperated with the Station.

IRRIGATION.

A new line of experimenting was undertaken in 1895, in the form of tests of the effects of irrigation upon the production of strawberries. The work was done in coöperation with one of the prominent strawberry growers of the State, Mr. J. C. Eddy, of Simsbury, Conn., upon his own fields. The results were very successful and tend to confirm the impression that irrigation, not only of small fruits, but of other crops as well, may prove a much greater aid in their cultivation than has heretofore been supposed.

Owing to severe winter killing of the plants, and to large rainfall during the strawberry season, these experiments were of little value the last year. It is hoped to continue them, however, another season.

FIELD EXPERIMENTS.

These have been with fertilizers and with forage plants.

The experiments with fertilizers have been conducted mainly at the Station. Their object has been to study the influence of the different materials upon the amount and the feeding value of the crop; especially the influence of nitrogenous fertilizers upon the protein of the crop. The results indicate more and more clearly the advantage of nitrogen in fertilizers for grasses and cereals, and the bad economy of its use for legumes.

The experiments with forage plants have been practical tests of the growth of the crops in the field and the milk production when the fodder is eaten by cows. Here, again, the advantage of diversified forage crops to supplement pasture feed in Connecticut is brought out more and more clearly and fully with each year's experience.

BACTERIOLOGY OF DAIRY PRODUCTS.

The work on the bacteriology of dairy products has been continued during the past year by Prof. Conn and his assistant, Mr. Esten. It has been devoted mainly to the further investigation of the important subject of cream ripening. This part of the process of butter-making is now known to be one of fermentation, produced by the bacteria in the cream. These bacteria come from various sources in the dairy and the barn. The especial object of the experiments of the last year has been to get light upon the kinds of bacteria that are common in Connecticut dairies, their sources, and the influence they exert upon butter when they chance to get into the cream and grow during the ripening process. It is hoped that the investigations in this direction will bring information that will materially aid the butter-maker to exercise a better control over this important phase of his industry than he has been able to do in the past.

FOOD AND NUTRITION OF DOMESTIC ANIMALS.

The investigations have included: Analyses of feeding stuffs with determination of their fuel value; Studies of rations fed to milch cows on dairy farms; Digestion experiments with sheep.

The analyses of feeding stuffs have been largely in connection with the feeding experiments with cows and sheep. Analyses have also been made of plants and crops grown on plots of land receiving different amounts and kinds of fertilizers. The number of analyses of feeding stuffs during the year is not far from one hundred and fifty.

The studies of rations fed to milch cows have been carried out on two dairy farms. The methods were like those followed in previous years. A representative of the Station visited each farm. A certain number of cows (about a dozen) were set aside for the experiment, which continued, in each case, from

four to twelve days. All the fodder of each kind fed the cows during the period and the milk given by each cow was weighed. Samples of the feeding stuffs were taken and sent to the Station for analysis, and the amount of fat in the milk was ascertained by the Babcock test on the ground. The results of these observations accord with and confirm still more strongly the doctrine which the Station has maintained — that most Connecticut farmers feed too wide a ration to their cows; that is, the feeding stuffs contain relatively too little nitrogenous matter.

It is worthy of note, however, that one of the farmers visited this year was feeding a ration as high in protein as that proposed by the Station and even higher, yet when this ration was made still more nitrogenous, the result, so far as the short experiment indicated, was pecuniarily profitable.

Such information as is obtained in these experiments has an especial value to other farmers; being the fruit of the actual experience of one of their fellow-workers, it has a meaning for them which it would not have if it came only from the Station. At the same time the Station experimenters reap a benefit from the direct work with the farmer, in that they learn better what are his wants and how to meet them. This coöperation between the Station and the practical farmer is a means of making direct practical application of the results of scientific research; it brings new information, and it is one of the most effective means for the dissemination of knowledge. Thus, in a three-fold way, it benefits the public, which the Station is endeavoring to serve.

The digestion experiments with sheep are similar to those previously reported. Their object is to learn what proportions of the nutritive ingredients of different feeding stuffs are actually digestible. As the results of such experimenting in Europe and in this country accumulate it becomes more and more probable that the different ruminants, as cows, oxen, sheep, and goats, digest very nearly the same amounts of protein, carbohydrates, and other nutritive ingredients from the same kinds of feeding stuffs. Hence the experiments on the digestion of different materials by sheep may be taken as an approximate measure of the digestibility of the same materials by milch cows. The greater convenience of handling sheep in

such experiments is the reason for using them instead of cows for testing the digestibility of some of the feeding stuffs of importance in the State. The experiments of the past year have been chiefly with green fodders and hays. In two cases milling products were fed in addition to the hay.

FOOD AND NUTRITION OF MAN.

The inquiries under this subject have been conducted for the most part in coöperation with the United States Department of Agriculture. They have included: Analyses of food materials; Studies of dietaries of families; Experiments upon the loss of nutritive material from potatoes when they are cooked in different ways; Digestion experiments with men; Experiments with men in the respiration calorimeter.

Analyses.—Not far from fifty analyses of specimens of articles used for the food of man have been made in connection with the dietary, digestion, and respiration experiments.

The experiments on the cooking of potatoes were intended to get light on the amounts of nutriment which are lost from potatoes in boiling in different ways. When boiled with the skins on the loss was too small to be of consequence, but when boiled with the skins off the loss was quite considerable.

The dietary studies are made by weighing, measuring, and analyzing the food purchased and consumed by a given number of people—a family for instance—during a certain number of days, and noting how the amounts and nutritive ingredients of the food compare with physiological standards, and how the actual cost compares with what the same amount of nutriment would have cost in more economical forms. The present Report includes studies of three dietaries of farmers' families, one of the Station agriculturist's family, two of poor families in Hartford, and three others which can be assigned to no particular class. These studies as they accumulate are useful, not only in bringing out the peculiarities of dietary usage of the different families, their methods of purchase and preparation of foods, the amounts of food wasted, and the ways in which improvements could be made to the advantage of both health and purse, but also in throwing light upon the general habits of living of people of various classes, such as farmers, mechanics, and those in business and professional life. The

food of people of the poorer classes is also being made a subject of study with results that are likewise extremely interesting.

Digestion Experiments.—A large number of experiments have been made in Europe, and of late in this country, to test the digestibility of various feeding stuffs by domestic animals. It is certainly as desirable to understand the digestibility of the food used by man as that of feeding stuffs used by domestic animals. Within a few years past a considerable number of digestion experiments with men, and some with children, have been made in European laboratories. In connection with the series of food investigations to which those carried on by the Storrs Station belong, such experiments have been undertaken in several institutions in this country. A considerable number have been carried out in connection with the Storrs Station during the past two years.

Twelve such experiments made with healthy men, by the Station alone or in coöperation with the Department of Agriculture, are described in the present Report. The method followed in these experiments is similar to that used in the tests of the digestibility of feeding stuffs by animals. It consists in weighing and analyzing both the food eaten and the undigested residue, and thus obtaining a measure of the proportions of the different nutritive ingredients of the food actually digested by the persons under experiment.

Compilation of the Results of Analyses and of Experiments on Digestibility of Foods.—In the Report of this Station for 1891, tables were given showing the results of analyses of American food materials. These included several hundred analyses of which the larger part had been made by the writer and his associates. Since that time the number of analyses has rapidly increased. A compilation lately made in behalf of the Office of Experiment Stations of the United States Department of Agriculture includes analyses of nearly 3,000 specimens of animal and vegetable food materials. This compilation is intended to include all of the analyses of such products that could be found up to July 1, 1896, exclusive of dairy products, sugars, and some other materials of which the number of analyses, especially for commercial purposes, is large, and the

results are so difficult to obtain as to make a complete compilation difficult, as indeed it is unnecessary. Of the analyses thus compiled not far from 1,300 have been made by the writer and his associates, and not far from 700 by others in connection with the series of coöperative food investigations now being conducted under the auspices of the Department of Agriculture. The larger number of the rest were by the Division of Chemistry of the United States Department of Agriculture, which has also made great numbers of analyses of the classes of food materials of which the complete compilation was not attempted for the reason just stated.

We have thus to-day a reasonably fair idea of the chemical composition of the food materials most commonly used in the United States. Their nutritive value, however, depends upon not only the proportions of the different nutrients—protein, fats, carbohydrates, etc.—but also upon the amounts of those nutrients which can be actually digested and used by the body for its nourishment. The object of the digestion experiments above referred to is to get light upon this latter factor—that of the nutritive value.

Another factor of the value of food for nourishment is what is called the fuel value, *i. e.*, the amount of potential energy in the food which can be transferred in the body into heat, muscular power, or other forms of energy.

Table of Percentages of Digestible Nutrients and Fuel Values of Foods.—While the information on these latter and kindred subjects now available is far from sufficient to show the exact values of different kinds of food for the nourishment of the body, enough has already accumulated to warrant the preparation of a reference table giving the estimated average amounts of actual digestible nutrients in a number of the materials most commonly used for the nutrition of man. Such a table has been prepared and is printed in the present Report. As explained in the description which accompanies this table, the figures are not given as showing exactly the average composition, digestibility, and nutritive value of each class of food materials. Many more analyses and experiments will be needed to show the range of variation and the actual averages of both composition and digestibility. The estimates of fuel

values likewise are only approximations. Much more experimenting will also be needed to show, as accurately as we need to know, just how the different ingredients of the several classes of food materials are used in the body, and just what are the requirements of people in different classes, and under different conditions, for proper nourishment. When, however, we consider that, twelve years ago, we had extremely little accurate information about the chemical composition and nutritive values of American food materials, and were obliged to look to European sources for nearly all of our information upon these subjects, and to depend upon analyses of European products for estimates of the composition of food materials produced in this country, the fact that such a table can be prepared from data which has been accumulated mostly in this country during so short a period is, most assuredly, a cheering mark of progress.

Heats of Combustion and Fuel Values of Foods and Feeding Stuffs.—In all the foods and feeding stuffs analyzed during the past year, the heats of combustion, which are taken as measures of the fuel value, have been determined by the bomb calorimeter. An account of this apparatus was given in the Annual Report for 1894. It has since been further elaborated, and is now being made for other institutions, several of which already have it use.

Experiments with Men in the Respiration Calorimeter.—Previous annual reports have contained brief reference to this apparatus, which has been for some time in process of development. As was there explained, the more purely scientific purpose is the study of the application of the laws of the conservation of matter and energy in the living organism. At the same time it has a most intensely practical purpose, namely, to learn more of the laws of nutrition and the ways the food is used in the body. To obtain this most useful knowledge, abstract research of the highest order is necessary.

The experiments are made by placing a man inside a box or chamber under conditions which permit the measurement of the income and outgo of his body. Arrangements are made for ventilating the chamber by a current of air which is measured and is analyzed as it goes in and comes out, so that the

products of respiration are determined. In this respect the apparatus is similar to those which are used in a number of places for experiments on the income and outgo (metabolism) of matter, and to which the name respiration apparatus is commonly given. Provision is also made for weighing and analyzing all the food and drink, and the solid and liquid excreta as well. By comparing the chemical elements and compounds received by the body in food, drink, and exhaled air with those given off in the solid and liquid forms by the intestines and kidneys, and in the form of carbonic acid gas, water, vapor, and otherwise by respiration and perspiration through the lungs and skin, we are enabled to strike a balance between the total income and outgo of matter in the man's body. We thus measure, on the one hand, the total food and drink consumed, their ingredients, the proportions of the several nutrients actually digested and taken into the blood to be used, and on the other, the quantities of material given off from the body during the period of the experiment. These data, taken in connection with what is known of the physiological processes that go on in the body, give more accurate information than can otherwise be obtained regarding the ways in which the food is used, and the quantities of different food ingredients that are needed to supply the demands of the body for various purposes of work and rest. Experiments of this kind are commonly known as respiration experiments.

The experiments, as above described, show the balance of income and outgo of chemical elements and compounds, and serve for the study of the metabolism of material in the body. It is desirable, however, to study the metabolism of energy. To this end it is necessary to know the potential energy of the food and drink, on the one hand, and, on the other, the potential energy of the excreta and the amounts of energy given off in the form of heat, external muscular work, and otherwise. The measurements of the potential energy of the food and excreta are made with the bomb calorimeter. The determination of the heat given off from the body is attempted by certain arrangements connected with the respiration apparatus, which have led to the use of the term respiration calorimeter. The accurate measurement of the heat is a matter which presents numerous difficulties. It appears, however, that these have

been for the most part overcome, and the prospect for final success seems very good.

Meanwhile a number of respiration experiments have been made and are described in some detail in the present Report. In each one, the subject, a man, remained in the apparatus from fifty-four hours to twelve days. The results show very clearly the gain or loss of protein and fat in the body with different kinds and amounts of food and under different conditions of work and rest. The success with these experiments has been very gratifying, and the promise for the future is, at present, even more so.

The full details of these experiments have been transmitted to the Department of Agriculture for publication, and it is hence deemed necessary to give only the principal results in the present Report.

STATE APPROPRIATION FOR INVESTIGATION OF FOOD ECONOMY.

The General Assembly at its last session provided an annual appropriation of $1,800 for the Storrs Station, to be used "for the purpose of investigating the economy of the food and nutrition of man, and for investigations of the bacteria of milk, butter, and cheese, and their effect in dairying." With this very material help the Station is able to greatly increase the amount and value of its inquiries in these directions.

GOVERNMENT COÖPERATION IN FOOD INVESTIGATIONS.

Among the numerous objects of agriculture the chief is the production of food for man. That the experiment stations in the country have hitherto studied the soil, the plant, and the animal, and their food and nutrition, and have given but little attention to the food of man, is not the fault of the stations. It is due simply to the fact that the primary purpose has been to help the farmer to improve his farming rather than to help the people at large to improve their food economy. It was for this reason that the original Act of Congress providing for experiment stations in all of the States and Territories did not include experiments upon the food and nutrition of man as a part of the work which it called upon the stations to perform. In 1894, however, the legislation with reference to the stations was so changed by Congress as to specifically authorize inquiries of this latter kind. At the same time an appropriation of $10,000

was made for the fiscal year ending June 30, 1895, to promote especial inquiry into the food economy of the people of the United States. The appropriation has been increased in the succeeding years to $15,000. The general government has thus formally recognized the important fact that the food of the people of this country for which wage workers spend half their income and upon which our health and capacity for work so intimately depend, is as proper a subject for experimental study as the food of the farmers' crops and cattle.

The responsibility for the expenditure of the Government appropriation referred to is given by Congress to the Secretary of Agriculture, who has assigned the inquiry to the Office of Experiment Stations. The conditions of the Act of Congress are such as to favor coöperation between the Department and other institutions of research, especially the experiment stations in different parts of the country. Accordingly, while a part of the work is done under the immediate direction of the Department, a considerable portion is being carried out in coöperation with experiment stations, colleges, and other organizations, including the Storrs Station, to whose Director the immediate charge of the enterprise is entrusted.

At present all of the food investigations of the Station are being conducted in coöperation with the general government, by which a considerable share of the expense is paid. By such coöperation a much larger amount of research is being carried on by the Station than the State appropriation provides for, and, at the same time, the contribution by this State to the enterprise is made much more fully available to the country at large. There is a like coöperation in the publication of the results of the inquiry. In this way the practical results of the work of the Station are made available to the citizens of the State, through the Station Reports and Bulletins, while much of the more technical details which are of decided scientific importance, but of less special interest to farmers and the public at large, are published by the general government.

W. O. ATWATER,
Director.

BACTERIA IN THE DAIRY.

XI.—FURTHER EXPERIMENTS IN CREAM RIPENING—FLAVOR, AROMA, ACID.

BY H. W. CONN, PH. D.

During the past few years the problem of cream ripening has been forcing itself more and more upon the attention of butter-makers. The objects of ripening cream are to make churning easier, to increase the yield of butter, and improve its flavor and aroma. The first two purposes have been discussed in Bulletins of this Station.* It has been known for some years that the flavor, the aroma, and the acid which are produced in cream during its ripening, and which give the peculiar character to the butter made therefrom, are due to the growth of bacteria in the cream. The real source, however, of the flavor is the cream itself, and the quality of the cream undoubtedly affects the character of the flavor. But in order to develop the proper flavor this cream must undergo certain chemical changes, and these changes are brought about by bacteria, which multiply in the cream with incredible rapidity during the ripening process. Experiments hitherto have been largely confined to a few selected species of bacteria, and we have had very little knowledge in regard to the effect produced upon the butter by the many different species of bacteria commonly found in milk and cream.

ACID, FLAVOR, AROMA.

It has been found that ripening is practically always accompanied by a souring of the cream, so much so that in most

* Some of the results have been given in the publications of the Station, as follows: *Bacteria in Milk, Cream, and Butter*, Bulletin 4 and Annual Report for 1889, pp. 52-67. *Ripening of Cream*, Annual Report for 1890, pp. 136-167. *A Micrococcus of Bitter Milk*, Report for 1891, pp. 158-162. *The Isolation of Rennet from Bacteria Cultures*, Report for 1892, pp. 106-126. *The Ripening of Cream by Artificial Cultures of Bacteria*, Bulletin 12 and Report for 1893, pp. 43-68. *Experiments in Ripening Cream with Bacillus No. 41*, Annual Report for 1894, pp. 57-68. *Some Observations of the Number of Bacteria in Dairy Products*, Annual Report for 1894, pp. 69-77. *Cream Ripening with Pure Cultures of Bacteria*, Annual Report for 1894, pp. 77-91. *A Year's Experience with Bacillus No. 41 in General Dairying*, Annual Report for 1895, Part I., pp. 17-40. See also *The Fermentations of Milk*, Experiment Station Bulletin No. 9 of the Office of Experiment Stations of the United States Department of Agriculture.

parts of the world it is called "cream souring." It has been found that good flavors are especially developed by the acid-forming species of bacteria. It has been assumed, therefore, that the development of flavor and the development of acid are essentially identical, or at least necessarily associated. Some practical, as well as scientific, butter-makers are teaching that one essential point to be aimed at in the cream ripening is to cause the acid-producing organisms to grow rapidly in order to develop an acid and flavor before the other organisms have a chance to increase. The fact that the extent of the ripening is determined by the amount of acidity conveys the impression that the ripening and the souring are identical. The idea was advanced by myself, however, some years ago, that flavor production is independent of acid production, and while many of the acid-producing species also produce changes in the cream which give rise to a good flavor, equally good flavors may be obtained by species of bacteria that produce no acid, and that some species of bacteria may produce acid in abundance without giving rise to the proper flavor. This conclusion was also reached by other bacteriologists. Storch, who first worked with pure bacteria cultures for cream ripening, found some species producing acid but not good flavor, and the same results were reached by Weigmann.

The relation of ripening to the aroma of butter is also an uncertain one. There are several pure cultures used in different dairying countries for artificially ripening cream, most of which produce favorable results so far as concerns acids and flavors, but none of which appears to give a satisfactory aroma.

Each of these three factors seems to be essential to a proper cream ripening, and we cannot hope to satisfactorily control this ripening until we know how and under what condition flavor, acid, and aroma are produced. Plainly, if we find that all three are produced by the same conditions and by the same species of bacteria, our method of handling cream for butter-making will be determined by this fact; while if we find that they are produced by different and independent agencies, the method of handling cream must be different.

The final settlement of these questions can only be reached after a long series of experiments. To determine accurately the relation of flavor and aroma to bacterial growth it has

appeared to me to be necessary to experiment, not with one or two, or with half a dozen, species, as has been generally done by bacteriologists hitherto, but with as large a number of the species of dairy bacteria as is possible. For two years or more I have been engaged in testing the effect upon cream ripening of the various kinds of bacteria which have been found in milk and cream. Some of these experiments have been reported in earlier publications. The present series began in May, 1895. In this work I have been assisted by Mr. William Esten, who has carried out a large portion of the practical experiments.

BACTERIA OF ORDINARY CREAM.

The first task in this series of experiments was to collect from creameries and from dairies a large variety of bacteria. It was especially desirable to obtain those found in creameries during the months of May and June, inasmuch as these months are commonly characterized by the production of the best quality of butter. During May and June of 1895 quite a number of visits were made to creameries in Connecticut, including those at Cromwell, Durham, Wapping, Elmwood, Farmington, and Ellington. Some of these creameries were visited two or three times, others only once. From the cream thus obtained as many different species of bacteria as possible were taken at once and set aside for future work. At subsequent periods other visits have been made to the same places. Other samples of milk and cream have been obtained from dairies at Storrs, and from two or three different dairies in Middletown. From these various sources nearly one hundred different types of bacteria have been obtained, most of which have been carefully studied and tested in cream ripening.

In thus describing them as different types I would not imply that they are necessarily different species, but simply that they show some differences in their method of growth. Bacteriologists do not yet know what constitutes a species among these organisms, and it is extremely probable that some of the hundred referred to really belong to the same species of bacteria, some of them being only slight variations of others. They all produce different effects, and have consequently been studied independently of each other. All of the general types of milk bacteria are included among this list. It includes some

bacteria which sour milk by producing lactic acid, others which curdle the milk by producing a rennet-like ferment, but rendering the milk alkaline, others, again, which exert a putrefactive effect upon the milk, and still others that have seemingly no effect whatsoever upon the milk or cream. The various types were in almost equal abundance among the species collected, except that the number of forms that have no appreciable effect upon milk is considerably larger than those belonging to any of the other classes.

In the early summer the variety of bacteria in the cream has been found to be greater than at the other seasons of the year thus far tested. No examinations have yet been made of the cream of the late summer or early fall. In nearly all of the samples of cream collected in May, and particularly in June, the number of different species was very great, not only when different samples were compared with each other, but in the same sample of cream. This would naturally have been anticipated, and is probably closely associated with the green food of the cows. It appears not unlikely that in this fact lies the explanation of the high quality of butter flavor commonly developed during these months. Not only is the variety greater, but the number of bacteria in the cream during these months is vastly in excess of that found under similar conditions in the cooler months of the year. No accurate quantitative tests were made, but the difference in the number of bacteria found in the samples of cream tested in June and those tested in February was very great indeed, even though the age of the cream was the same in the two cases. This fact is, of course, due to the temperature which stimulates bacterial growth.

Another point in the same connection is the difference in the species of bacteria found at the same creamery at different times. Such samples, even though following each other at short intervals, showed a considerable difference in the types of bacteria found. This is in part due to the fact that no bacteriological examination of cream can disclose all of the kinds of bacteria therein, and the bacteriological analysis is, therefore, in every case, very incomplete. Two samples of the same cream would doubtless show some differences for this reason. But this is not wholly the explanation of the matter,

since it was frequently found that a sample of cream taken at one date would disclose a large number of bacteria which liquefied gelatine, while another taken a few days later would show no liquefying bacteria. The presence of the liquefying organisms is most easily determined; in fact one can never fail to detect them. Their presence in quantity in some cases, and their absence in others is, therefore, significant.

Variation with the Cow.—One series of experiments consisted in the testing of the milk from eight cows in the same barn. These cows were kept in adjoining stalls and fed in the same manner, and their milk was drawn into sterilized bottles and then tested separately. After a few weeks the same eight cows were again tested in the same way, and the same test was repeated at short intervals for several months. It was found in these tests that there was the most striking difference between the bacteria in the milk of the separate cows. The *number* varied surprisingly. The milk from two of the cows contained not more than 250 bacteria per loop full (a loop full is a drop about the size of the head of a large pin), while the milk from a third, contained 20,000, and a fourth, 60,000, in the same quantity of milk. The *variety* of bacteria was no less interesting. In the first place, it was found that no two of these eight samples of milk, when left to themselves and carefully guarded from outside contamination, underwent the same kind of fermentation. Some of them curdled and soured, some of them curdled without souring, some developed a cheesy odor, others a putrefactive odor, and, among the lot, there was one cow that gave milk that became slimy. When the same cows were tested a second time, a few weeks later, the effects were different. The cow that previously gave slimy milk, no longer produced milk with this defect, and all of the samples but one soured, although not in the same way in any two cases. In the third test still other variations occurred. When the bacteria from the eight samples were studied, it was found, as was to be expected, that there was a good deal of variation. There were one or two species that were common to nearly all of the cows, while others were found in one lot of milk, and others, again, in one or two lots. It must be always kept in mind that these bacteria of which we are now speaking do not come

from within the milk gland, but only from the milk ducts. They do not, therefore, come from within the animal, but really from the exterior. They are bacteria from external sources, which have made their way into the ducts, and not bacteria from within the animal making their way out. This difference in the bacterial flora of milk from cows in the same barn is certainly a somewhat surprising and interesting fact. It gives us a suggestion as to the complex mixture of bacteria in cream of an ordinary creamery coming from hundreds of cows. It shows further how impossible it must be to obtain a uniform quality of cream (so far as bacteria are concerned) from many contributing sources.

METHOD OF EXPERIMENT.

The method of experiment has been to separate a lot of cream from the milk by a centrifugal machine and then divide it into four equal parts. In more recent experiments a larger amount of cream was taken and eight experiments were carried parallel with each other. All of the cream was heated to a temperature of 69°–70° C. (156°–158° F.) for fifteen minutes and then allowed to cool. This heating (pasteurizing) destroyed most of the bacteria which chanced to be present in the cream, only such bacteria as produce spores remaining alive. Experience has shown that such heating will kill all the lactic bacteria.

The species of bacterium to be tested was grown in sterilized milk. Two days before the experiment began a sufficient number of vessels of sterilized milk were inoculated, each with a different species of bacterium. These were then allowed to grow for two days. When the lots of cream were pasteurized and cooled, as above described, one of these milk starters was poured into each. Each of the lot received a starter made from a different species of bacterium, and one lot was always left for a control experiment without any starter.

The four samples were then placed under similar conditions as to temperature and allowed to ripen for the same length of time. After considerable experience it was found that the most satisfactory method of procedure was to use a ripening of forty-eight hours at a somewhat high temperature (about 21° C., 70° F.). After the ripening the cream was cooled and

churned. The examination of the butter was made, in most cases, without salting, inasmuch as salting very commonly obscures the peculiar flavors developed during the ripening process. The testing was made for flavor, for acid, and for aroma. In the records that were kept it was difficult in many cases to know exactly how to describe the flavor or aroma of a lot of butter. The flavors and odors that develop as a result of the ripening of different species of bacteria are highly variable, and the words in our language for the description of either flavors or odors are entirely inadequate to any considerable accuracy. Inasmuch, however, as the problem was chiefly to determine the relation to butter-making, the record was made from this standpoint, and the butter was described either as possessing a good, a bad, or an indifferent flavor, or as having a typical, or an unusual aroma, or no aroma. It must be recognized also that tastes differ, and a flavor which has appeared to me to be good might not always so appear to others. While, therefore, the classification is not as accurate as might be scientifically desired, it is sufficiently accurate for determining the relation of the various bacteria to butter-making and to the normal flavor and aroma.

It will be evident from this description of the method of experiment that the tests have always been made in very small lots of cream. There are some decided advantages and some decided disadvantages in this method. The disadvantage is in the fact that tests in such small lots cannot be relied upon to produce very good results or truly normal butter. First-class butter, as is well known, cannot be made without attending very strictly to all conditions, and manifestly when butter is made in lots of half a pound or so it is impossible to control the results satisfactorily. On the other hand, however, it is a far easier matter to compare results obtained by different species of bacteria if they can be directly compared with each other. When we have six or more samples of butter made from the same lot of cream, and under identical conditions, except that the species of bacteria used in ripening is different, a comparison between the flavors and aromas is more valuable than if these tests were made upon different days from different lots of cream. Inasmuch as these experiments were designed to test the general effects of many species rather than

to find out the particular species which produced the best butter, I have thought that this method of testing several species simultaneously promised the most valuable results.

RESULTS.

In general the results of these experiments have been confirmatory of those of the series already given in a previous publication (Bulletin No. 12). Nevertheless, a number of new facts of interest and importance have appeared. The most important of these results are the following:

CONTROL CREAM COMPARED WITH INOCULATED CREAM.

First.—One of the most interesting facts was found in comparing the control (*i. e.*, the pasteurized but not inoculated) samples of cream, and butter made therefrom with the inoculated samples. As a rule the control butter possessed neither flavor nor aroma—in no case unless the ripening had continued too long. Nevertheless, it was found in many cases that the control cream *did* undergo some decided changes during the period of ripening. The temperature of 158° F. (used in pasteurizing) does not kill all the bacteria in the cream, and the subsequent ripening being somewhat long and the temperature somewhat high, the few bacteria that were left in the cream after pasteurization had an opportunity to develop. The cream thus frequently showed the effects of their presence. In many cases the control cream was thick and nearly curdled, but inasmuch as it was never acid, it was plain that this effect was due, not to the lactic acid organisms, but rather to the growth of the species of bacteria which curdle milk by the production of a rennet ferment; a class frequently called the putrefactive class of bacteria. This is readily understood, since these bacteria frequently produce spores which resist heat, while the acid bacteria produce no spores. In a few cases the control cream became slightly bitter or developed some other unusual taste, but the taste was so slight that it had no effect upon the butter made from the cream. These facts, of course, are not surprising, for they are exactly what would have been expected when we remember that pasteurization does not destroy all the bacteria present in the cream. The interesting fact in these experiments was that in no case did the inoculated lots of cream show similar results. Where the control cream

became bitter none of the three inoculated samples showed the slightest trace of bitterness. Where the control cream showed a partial curdling, the inoculated samples showed an entirely independent effect that was evidently due directly to the influence of the inoculated species and not to those left in the cream after pasteurizing. In some cases the inoculated cream was thickened and curdled from the effects of the bacteria with which it had been inoculated, but, in other cases, where the inoculated species had no power of curdling the cream, the cream at the end of the ripening was as thin as at the beginning, showing no trace of curdling even though the control cream was at the same time very thick. These results were not in one or two cases, but in a great number of experiments. The result at first surprised me, but it was found to be so general that I soon came to look upon it as normal and to expect it.

WHY "STARTERS" ARE BENEFICIAL.

The importance and significance of this fact is considerable. If the control develops a bitter taste, while the inoculated species does not, this can only be because certain bacteria grow in the control which do not grow to an equal extent in the inoculated cream. When cream is inoculated with one kind of bacteria in considerable quantity, other species of bacteria already present may be checked in their development by the growth of the inoculated species and prevented from producing their normal results. The control and the inoculated cream must have had at the end of pasteurization the same kind of bacteria present, but the inoculation of the cream with one species of bacteria in the artificial culture prevented those in the cream either from growing or from having their normal effect upon the cream.

This result is, indeed, not very surprising after all. Bacteriologists have for some time known that different species of bacteria may thus have a repressing influence upon each other. It has been determined, for instance, that the growth of the normal bacteria in milk prevents the growth there of the cholera bacillus, although the cholera bacillus will grow readily in milk that has been sterilized. Many other similar instances have been found, indicating that this is not an unusual but rather a common effect where different kinds of bacteria are

growing side by side. The importance of the matter to the butter-maker is considerable, inasmuch as it indicates that it may be possible, by inoculating cream quite heavily with one kind of bacteria, to check the influence of the other kinds which may be present. One can thus obtain the influence of the inoculated species but little modified by the growth of the other bacteria which are present in less abundance. During the last year or two butter-makers have become convinced of the advantage of using starters. They have found that in many cases the use of a starter, either a natural starter or one of the various pure cultures which are on the market, will improve their butter where it is added to ordinary cream. It has been something of a question how a starter can do any good in cream already more or less impregnated with bacteria. But if, as these experiments show, such a starter has the power of checking the growth of normal bacteria, we can understand the matter. If starters can have any influence checking the growth of bacteria already present we should expect that such starters would frequently improve butter, although not always. Thus, the facts here given offer an explanation of and emphasize the value of a starter of some kind in cream, both for the purpose of starting the proper kind of ripening, and also to check the development of many bacteria already present which might be injurious to the butter.

MOST BACTERIA HARMLESS OR BENEFICIAL.

Second.—The majority of the species tested may be regarded as indifferent in their effect upon the butter. About half of them when used to ripen the cream, as will be seen in the experiments described below, produced butter that had neither flavor nor aroma nor acid, and the butter was practically indistinguishable from the control butter. These species are the largest in number and present in the greatest variety around barns and dairies. They are perfectly wholesome in the cream. They do no injury, they do no special good, and we may, therefore, conclude from this that the majority of the species of bacteria that are present in the sources of our milk are wholesome forms, which may grow and develop in the cream without producing any trouble, and are perfectly consistent with the best quality of butter.

Third.—A considerable portion of the species found are positively favorable in their influence upon the butter. Of the sixty-eight species tested, twenty produced butter that has been described in our notes as good flavored. Of course the flavor was somewhat variable and its good character, while sometimes striking, was at other times moderate. It was not always the typical butter flavor and yet was such an approximation toward it that the butter would be regarded as of a good quality.

Fourth.—A smaller number of species produced injurious effects upon the butter; eighteen species among the sixty-eight tested have been described as producing butter that was bad, or poor, or strong flavored, or disagreeable; various adjectives being used to indicate the different effects. Some times the poor flavor was a putrefactive taste, in other cases it was a bitter taste; in others, again, a strong sour taste; while in still others the effect was of a peculiar indescribable character. In many of these eighteen species the pleasant flavor was very slight, and probably insufficient to materially injure the butter.

FLAVOR INDEPENDENT OF ACID.

Fifth.—Of the species of bacteria producing good flavors in the butter, many were of the acid-producing class. Of the twenty above mentioned, nine were lactic organisms. On the other hand, eleven were among the class which would be described as alkaline species, by which it is meant that they either produced an alkaline reaction in the milk or produced no change in its reaction. They are at all events distinctly not acid forms. Seven among them liquefy gelatine and are, therefore, among what are called the putrefactive bacteria. In thus speaking of the flavor, we have always tried to carefully distinguish flavor from acid taste. The flavors produced by the acid species (leaving out of account the sour taste resulting from the acid), and those produced by the other class were not particularly different. Independent of the acid it is doubtful whether there was enough difference in the flavors produced by the two classes of organisms to enable us to separate them from each other in this way.

Sixth.—Of the eighteen species described as producing injurious effects upon the flavor of the butter, nine belonged to

the acid-producing class, while nine belonged to the class developing alkaline reaction.

From these facts it appears to me a safe and perfectly legitimate inference that flavor is a matter entirely distinct from acid. It will be noticed that among the acid-producing species there are some that develop good flavor, while others develop a decidedly unpleasant flavor; and it will be noticed that among the species producing good flavors in the butter, while many of them are acid producers, a large number, eleven out of twenty, are among those that develop no acid. In speaking of the flavor as entirely distinct from the acid it is, of course, not meant to imply that they may not be associated. It may commonly happen, as will be noticed from these results, that the same species of bacteria may develop acid and flavor. This undoubtedly is the case with many of the bacteria of milk, and with most of the species of bacteria that are used by various butter-makers as cultures for artificial fermentation. Nevertheless, the fact that many of the species of bacteria produce acid and, at the same time, an unpleasant flavor and disagreeable effect upon the butter, while pleasant flavors are developed by species of bacteria which have not the acid-producing power, indicates clearly enough that the development of acid is not the same thing as the development of flavor. The development of the acid comes, as is well known, from the decomposition of the milk sugar, but the development of flavor comes, at all events, not from the same kind of decomposition of the milk sugar, and probably comes from some other kind of decomposition effect produced by these bacteria upon some of the ingredients of the cream. It is impossible at the present time to state, any more closely, to what the flavor is due, but the facts outlined above show clearly enough that the development of flavor and the development of the acid are not identical, and that while acid organisms may be the most promising ones for giving rise to the proper flavor in cream, these flavors may be due in many cases to organisms of an entirely different character. While, therefore, the lactic bacteria may be regarded as commonly producing the butter flavor in practical butter-making, they do not do this simply because they produce acid, and we must recognize that other types of bacteria probably assist in producing the desired flavor. It is important to note

in this connection that of the thirty species described as indifferent in their action, none were acid organisms

AROMA INDEPENDENT OF FLAVOR AND ACID.

Seventh.—Perhaps the most interesting result has to do with the production of the butter aroma. The butter aroma, the character that affects the nose rather than the palate, appears to be, at least so far as the results of the experiments are concerned, entirely independent of the flavor. Moreover, it appears to be a more unusual thing for bacteria to produce a desirable aroma than a desirable flavor. The great majority of these species tested give rise to practically none, or at least to an extremely slight aroma. Of sixty-five species whose effect on aroma is given below, thirty-nine produce no aroma at all. Of the species of bacteria which thus have no influence upon the aroma of butter, the majority, again, are among the class which either develop an alkaline reaction in the cream or do not change its reaction at all. Seven of those producing no aroma are among the class that produce lactic acid. Among those that do produce an aroma of a decided character, eighteen are described in my laboratory notes as producing an unpleasant or a bad aroma; seven of these are among those that produce lactic acid. The kind of aroma developed varied widely in these different species. Some times it was an extremely sour smell, at other times it was in a measure putrefactive. In most cases the aroma was of a character that was indescribable, from the lack of proper terms, but always unpleasant, and would always be regarded as characterizing a poor quality of butter. Among the sixty species studied, only eight have been found as yet to produce an aroma which has been described in my notes as good; and in only three has the aroma been that which is looked for in first-class butter. In two or three cases the aroma produced was of an extremely fine character, and in these artificial tests almost identical with the aroma expected in the first-class butter from a creamery. It has been interesting to find that, of the eight species which produce the aroma which has been described as good, none has been among the acid-producing organisms. The eight either develop an alkaline reaction or have no special effect upon the reaction of milk. There were three which developed the most typical aroma of all the species studied, Nos. 66, 69, and 104.

Two of these curdled milk by producing a rennet, both liquefying gelatine. The third did not curdle the milk. This result has been a surprise to me, inasmuch as I had supposed before the experiments began that the aroma was a matter very closely associated with the development of the lactic acid. These experiments are not sufficient to settle this question completely, especially since only eight species have been found to produce a desired aroma. It may be that in further experiments now going on lactic acid species also will be found associated with the development of aroma. It is, however, interesting to note that in the hands of European bacteriologists, so far as their experiments have gone, somewhat similar results have been obtained. There are, upon the European markets, several different kinds of pure cultures of bacteria used by creameries for ripening their cream. All of them are of the lactic acid type, and none of them is capable of developing aroma to any considerable extent. Recent work of Weigmann further confirms this result.* While he is inclined to think that aroma may be produced by lactic organisms, he regards the aroma as distinct from the acid quality, and the species of bacterium which he experimented upon as producing the best aroma was not of the acid-forming class.

This result cannot be surprising, and is, indeed, what might have been expected. Beyond question the aroma is due to volatile products, and these would most naturally be expected as resulting from albuminous decomposition. Lactic acid itself, as is well known, has no odor at all, and while sour milk has a peculiar odor, this odor, as was pointed out by Lister long ago, must be due to certain other products besides the lactic acid. The butter aroma, however, is not the odor of sour milk, but is one distinctly different. It is consequently an interesting and important point if we find that this butter aroma is associated with a different class of organisms from those which produce lactic acid. Herein we may probably find a partial explanation of the reason that the aroma of butter developed during the months of May, June, and July is of a higher character than that produced during other months of the year, since, at this period, the cream, as already noticed, is provided with a larger variety of bacteria, and, therefore, among them

* *Milchzeitung*, 1896, p. 793.

there is a greater chance of finding not only those producing acid, but also some which give rise to an aroma.

It has been found in these experiments thus far that none of the species tested combines all of the three characters—the power of producing flavor, acid, and aroma. Some develop flavor with the acid, others develop aroma with flavor, and others develop aroma without any special flavor. As yet no single species has been discovered that produces all simultanesously. This result is not, of course, surprising, for, recognizing that the ripening of cream must be an extremely complicated process, and produced by a large number of species of bacteria working together, it is a natural inference that the different qualities in the butter may be caused by different species of bacteria. It is by no means to be implied, however, that the three properties may not be combined in some species of bacteria.

Lastly, it is interesting to note that among the species of bacteria which produce good flavor in the butter, are found some that were quite widely distributed during the month of June. There was one species in particular, which, in my experiments, was described as giving rise to a good flavor and a strong acid, which was found during the months of May and June in each of the creameries from which samples of cream were taken. This, of course, is suggestive as indicating perhaps a reason for the common production of a good quality of butter during these months.

SUMMARY.

1. The cream in ordinary creameries or in ordinary dairies always contains bacteria, a large majority of which are perfectly wholesome, and which give rise either to good flavors and aromas in the butter or, at least, produce no injurious effect upon the cream. They are perfectly consistent with the production of the best quality of butter.

2. In the months of May and June the variety and the number of these types of bacteria is decidedly greater than in the winter months, and this probably explains, in part, the better quality of butter at these seasons.

3. Occasionally a dairy or a creamery may be impregnated with a species of bacteria that grows rapidly and produces a

deleterious effect upon its butter. This will produce in all cases a falling off in the quality. The trouble may be due, perhaps, to a single cow, inasmuch as the milk of individual cows may sometimes contain species of organisms not found in others, even in the same barn. It is, however, commonly impossible for the farmer or the butter-maker to find the source of such injurious bacteria.

4. Creameries and dairies will in many cases be supplied with bacteria giving rise to desirable flavors, aromas, and a proper amount of acid. This is commonly the case from the fact that the good-flavoring species are abundant, but it will not always be true. It is more common in June than at other seasons of the year, simply because the variety of bacteria is greater at this time, and hence the greater likelihood that some species which produce the proper aroma and flavor will be present. Probably, also, some of the desirable species are especially abundant in the green food of cows in June.

5. If cream be inoculated with a large culture of some particular kind of bacteria, this species will frequently develop so rapidly as to check the growth of the other bacteria present and thus, perhaps, prevent them from producing their natural effects. Hence, it will follow that the use of starters will commonly give rise to favorable results, even though the cream is already somewhat largely impregnated with other species of bacteria before the inoculation with the artificial starter. This fact lies at the basis of the use of artificial starters either with or without pasteurization. To produce the desirable result it is necessary to have the starter contain a large abundance of some favorable species which by its growth can both check the development of the ordinary cream bacteria and can develop a proper flavor by itself.

DETAILS OF EXPERIMENTS.

Before describing the experiments in detail a few words more may be in place as to the method of experimentation and recording results. The method by which different species have been tested as concerns their influence upon cream ripening and butter have already been described. It will be seen from the method thus given that the comparisons between the effects of the different organisms upon butter have been made under conditions in which they can be strictly accurate. When

from four to eight lots of butter are made from the same lot of cream, when one of these lots is a control experiment made from cream without inoculation, it is possible to make very accurate comparisons between the different samples as they are examined one after the other. Under these circumstances, where marked differences appear in the flavors or the aromas, there can be no question that they are due to the action of the organism in question. In spite, therefore, of the objection that the butter made in these cases was seldom made under conditions which would give rise to the best quality of product, it is thought that the comparisons that have been made between them are more strictly accurate and more valuable than could have been made in any other way.

In regard to the records, I have been very much at loss to find any satisfactory way of recording results. The flavors have been very varied, but our descriptive terms are so crude as yet as to make it impossible to describe these flavors in such a way as to enable another person to recognize them. Few of the flavors which have been recognized are such as are commonly found in butter, and yet many of them have been so pleasant and so akin to butter flavors that I have been convinced that the butter flavor of ordinary butter may be made up of the combination of a number of the different flavors produced by the different species of bacteria. Still greater is this difficulty in regard to the records upon the aroma of the butter. There is practically no way of describing the aroma so that it can be distinguished by another person unless it chances to have a distinct similarity to some well-known odor. I have, therefore, been obliged in these experiments simply to speak of the flavors and aromas as pleasant or unpleasant, as typical or not of the typical character, and as, therefore, contributing in my own judgment to the good or the bad qualities of butter. I recognize also that different individuals would describe these results in a different way. In most cases Mr. Esten as well as myself made an examination of the butter, but our *descriptions* of the flavors and aromas seldom agreed, although we did agree in all cases as to whether a given aroma and flavor was pleasant, and, therefore, favorable to butter-making, or unpleasant, and, therefore, unfavorable to butter-making. In spite of this unsatisfactory condition of the records upon the action of

the organisms upon butter, it is thought that the general result, namely, the relations of the organisms to the production of normal, first-class butter, is reliable and is valuable.

The species of bacteria which have been used in the following experiments have been obtained at various times in the last two years from a variety of sources. All of them have come from dairy products, many of them directly from cream in creameries. Some have been derived from milk, some from the milk as it is drawn from the cow, others from the dust that has fallen from the cow during the milking, collected directly in gelatine plates. They may all, therefore, be regarded as distinctly dairy bacteria. These organisms have been carefully studied, and their characters determined in the laboratory before the butter experiments have been undertaken. It has been thought best, however, not to give here the detailed descriptions of these species. My list of Connecticut dairy bacteria is increasing, and each month is giving more information in regard to the relation of these bacteria to each other from a systematic standpoint. It is thought, therefore, that if the description of these species be reserved till a later date more valuable inferences can be made as to the distinctness of the types described and their relations to each other; and the results will, therefore, be a more valuable contribution to the vexed question of the limits of species among bacteria. These descriptions will, therefore, be reserved for later publications.

In the description of the butter-making experiments each organism is referred to by a number, which refers to the number in my own private list. There will be given in each case the source from which the organism was derived and its effect upon milk, inasmuch as these are factors directly concerned in the practical experiments to be described. Note will also be made of the power to liquefy gelatine, since this will in a measure distinguish the organisms which act on the albumens. The temperatures are all centigrade:

Species No. 21.

This is a slender bacillus which is extremely common in the dairies of Connecticut. It liquefies gelatine and produces a fluorescent green color, and is one of the most common of our organisms. It has the effect of curdling milk in about three days, rendering it very slightly alkaline. Some varieties of the species appear to digest milk without first curdling it. Its effect upon cream is

to thicken it, with a rather strong odor. The butter made therefrom is moderately good in flavor, but the flavor is so slight that the butter would not be regarded as good. There is no special effect upon the aroma unless over-ripened.

Species No. 31.

A slender bacillus which very slowly liquefies gelatine, turning it green. It is also a very common species in the dairies of Connecticut, having been found in many places. It curdles milk into a soft, slimy curd at 20° in about two days. A digestion of the curd begins at once and the milk finally becomes a yellowish green liquid with an alkaline reaction. Cream is slightly thickened by it, and the butter made therefrom, if the cream is not much ripened, is very flat and tasteless, with no special aroma. If the ripening continues further the butter is strong, tallowy and unpleasant. This organism, therefore, is unfavorable in its effect upon butter, producing undesirable flavors and aromas.

Species No. 63.

A short bacillus found at Elmwood, Conn. It renders the milk acid, curdling it after several days. Cream is filled with gas bubbles, is acid, and the butter made therefrom has a good, rich flavor, being decidedly good in character. Unfortunately, no note was taken at the time of the experiment of the aroma produced.

Species No. 64.

A bacillus found at Cromwell and also at Durham. It liquefies gelatine and digests milk into amphoteric or weak alkaline liquid, but with no proper curdling, and with rather an unpleasant odor. Butter made from the ripened cream possesses a good flavor and an aroma which is pleasant. The cream has a slight putrefactive odor, but the butter made therefrom does not show the effect of this odor unless highly ripened.

Species No. 65.

A micrococcus form found at Durham, Wapping, Elmwood, Cromwell and Storrs. It does not liquefy gelatine. It curdles milk in about two weeks, rendering it acid. Cream becomes pleasantly sour, slightly acid to litmus, and the butter made therefrom has an excellent, first-class, rich flavor. The aroma of the butter, however, is slight—at all events, not that of butter.

Species No. 66.

A bacillus found at Cromwell and at Storrs. It does not liquefy gelatine. Milk is not affected by it, except that it becomes slightly transparent and alkaline. Butter made from cream ripened with the organism develops an excellent flavor, which is described as "nutty," and has a good aroma. The butter has been described as first class, both in flavor and aroma.

Species No. 68.

A bacillus found at Cromwell. It liquefies gelatine and digests milk, sometimes without previous curdling and sometimes with a previous curdling. The digested milk is strongly alkaline. The cream inoculated with it develops a slight flavor, but the butter made therefrom is practically tasteless and has no aroma.

Species No. 69.

A bacterium found in Middletown. It liquefies gelatine, curdles milk in three to six days, and then digests the curd into a colorless alkaline liquid with a bitter taste. Cream is slightly thickened thereby, and the butter made from the cream has a sharp, almost bitter, sour taste, which is not specially pleasant, but the aroma is exceptionally fine, appearing to be identical with the aroma of the highest grade of butter. This fine aroma was developed in every case in which the experiment was made, and could hardly be distinguished from that of first-class market butter. The butter, however, was not first class, because the flavor was too sharp.

Species No. 70.

A micrococcus found at Durham. It does not liquefy gelatine, and has little effect upon milk. Butter made therefrom has a slight but good flavor; no noticeable aroma.

Species No. 71.

A bacillus found at Cromwell. It does not liquefy gelatine. Milk is curdled after three days at 36° and is slightly acid. Butter made from cream inoculated with it has a slightly sour taste, but a good flavor and no special aroma.

Species No. 72.

A bacterium found at Cromwell. Does not liquefy gelatine. It curdles milk at 36° in two days with an acid reaction. Butter made from cream inoculated with it has a very sour and decidedly unpleasant taste. When ripened sufficiently to develop flavor and aroma both are decidedly disagreeable, and the butter is very poor.

Species No. 73.

A bacillus found at Cromwell. It does not liquefy gelatine, and upon milk it appears to have no effect. Butter made from cream inoculated with it has a very slight flavor and aroma, not unpleasant, but so slight as to make the butter rather flat and tasteless.

Species No. 74.

A bacillus found at Durham, and also at Elmwood. It does not liquefy gelatine, and appears to have no effect upon milk, except to render it slightly slimy after about three weeks. Butter made from cream ripened by means of it has neither flavor nor aroma unless the ripening is continued too long, and then there develops a slight flavor of decay.

Species No. 75.

A micrococcus found at Durham. It does not liquefy gelatine. It has no effect upon milk, and produces butter which has neither appreciable flavor nor aroma.

Species No. 76.

A bacillus found at Durham. It does not liquefy gelatine, has no effect upon milk, and is absolutely without any influence upon either the flavor or the aroma of butter.

Species No. 77.

A bacillus found at Cromwell. It does not liquefy gelatine, and has no effect upon milk, except to render it slightly slimy. Butter made from cream inoculated with it develops a moderately good flavor and a good aroma, not very strong, but decidedly better in flavor and aroma than the control.

Species No. 78.

A micrococcus found at Ellington and at Storrs. It does not liquefy gelatine. It renders milk acid at 20° without curdling it. The acid is sufficient, however, to curdle the milk when it is boiled. At 35° the milk is curdled. Butter made from the cream develops a decidedly pleasant flavor, unless the ripening is too long, when the flavor is rather sharp and bitter. There is, however, no noticeable aroma. The organism develops flavor without aroma.

Species No. 79.

A bacterium found at Ellington. It does not liquefy gelatine. It renders milk acid, and sometimes curdles the milk after two weeks at a temperature of 20°, at other times not curdling the milk although rendering it acid. At 38° a curd is developed. The butter made from it is decidedly sour and unpleasant in flavor with no appreciable aroma.

Species No. 80.

A micrococcus found at Ellington. It does not liquefy gelatine, has no effect upon milk, and no effect upon either the flavor or the aroma of butter.

Species No. 82.

A bacillus found at Ellington. It does not liquefy gelatine, and has no effect upon milk at any temperature, and no effect upon either the flavor or the aroma of butter.

Species No. 83.

A bacillus found at Cromwell. It liquefies gelatine and curdles milk, rendering it slimy. The reaction is alkaline. The butter has a clean, sharp taste, with a yeasty aroma.

Species No. 84.

A bacillus found at Ellington. It does not liquefy gelatine, and has no effect upon milk except to render it slightly alkaline. It has no effect upon either the flavor or aroma of butter, the butter being tasteless.

Species No. 85.

A micrococcus found at Cromwell and at Storrs. It does not liquefy gelatine. It has no effect upon the milk, except to render it slightly alkaline and slightly slimy. It produces neither flavor nor aroma, the butter being tasteless.

Species No. 86.

A bacillus found at Cromwell. It does not liquefy gelatine. It does not curdle milk, but slowly digests it into a watery liquid which is alkaline. At 35° it is curdled and subsequently digested. Butter made from cream inoculated with it develops a strong taste of decay and a strong, unpleasant aroma. The butter is decidely unpleasant.

Species No. 87.

A bacillus found in Middletown. It does not liquefy gelatine nor curdle milk at 20°, though it renders it sufficiently acid to curdle when heated. At 35° the milk is curdled and rendered acid. Butter made from cream ripened with it is not pleasant. Neither the flavor nor the aroma is that of butter, but is somewhat similar to that of cooked milk.

Species No. 88.

A bacterium found at Canton. It liquefies gelatine and curdles the milk in six days, rendering it alkaline, and subsequently digests the curd. When allowed to ripen cream for a moderate length of time it produces no effect whatsoever upon the butter, neither taste nor aroma being noticeable.

Species No. 89.

A bacillus found at Cromwell. It does not liquefy gelatine but curdles milk in six days, rendering it acid. Cream is also thickened and soured, and butter made therefrom has too sour a taste to be pleasant. No record was made of the aroma.

Species No. 90.

A bacillus found at Elmwood. It does not liquefy gelatine and has no effect upon the milk except to produce slight alkalinity. Butter made from cream develops a decidedly pleasant flavor, though slight. There is also developed a slight pleasant aroma.

Species No. 91.

A bacillus found at Canton. It does not liquefy gelatine. It curdles milk in six to nine days into a hard acid curd with a decidedly sour odor. When allowed to ripen cream it develops a good flavor in the butter, though not very strong. No aroma whatsoever appears to be produced.

Species No. 92.

A bacillus found at Elmwood. It liquefies gelatine. At 20° it digests milk without curdling it, producing an alkaline solution. At 36° it first curdles the milk and subsequently digests the curd. Cream ripened with it produces butter without flavor or aroma. A strictly neutral species.

Species No. 93.

A bacterium found in Middletown. It does not liquefy gelatine nor curdle milk at 20°, though it renders it sufficiently acid to curdle when boiled. At 36° it curdles milk. Butter made from cream ripened by it has a sour and distinctly cheesy taste which is unpleasant. There is no butter aroma, though the cheesy aroma is noticeable.

Species No. 94.

A bacterium found at Elmwood and at Storrs. It does not liquefy gelatine but curdles milk in eleven to twelve days at 20° into a hard curd which is acid. Butter made from cream ripened by it is too sour to be good. A sour aroma also commonly developed. If the ripening be slight the flavor is not unpleasant, but the sour taste and aroma develop very quickly.

Species No. 95.

A bacterium found at Wapping. It does not liquefy gelatine and has no effect upon milk. It has little effect upon the butter, producing a very slight flavor, which is pleasant, but no aroma.

Species No. 96.

A bacillus found at Cromwell, and also at Middletown. It liquefies gelatine. Occasionally it curdles milk, rendering it slightly alkaline. It produces no effect upon the butter, either as to aroma or flavor.

Species No. 97.

A bacterium found at Ellington. It does not liquefy gelatine and has no effect upon milk. Butter is not affected by it, having neither flavor nor aroma.

Species No. 98.

A bacillus found at Cromwell. It does not liquefy gelatine and has no effect upon milk except to render it slightly alkaline and transparent. Butter made from cream ripened by it has very little flavor, but it has a peculiar, though rather unusual aroma, which is unpleasant, and not a typical butter aroma.

Species No. 100.

A bacterium found at Canton. It does not liquefy gelatine and has no effect upon milk. Cream ripened by it gives butter a pronounced flavor which is rather unpleasant when strong, and is not a normal butter flavor. Slight aroma is developed, which is much like that of good butter.

Species No. 101.

A bacillus found at Middletown, Cromwell and Storrs. It liquefies gelatine and curdles milk into a soft curd, with no change in reaction. The curd is slightly digested and develops a cheesy odor. Cream ripened by it produces butter with a moderately good but slightly cheesy flavor, and it has a cheesy aroma. The variety found at Storrs appears to be identical with the others, except that is does not develop a cheesy aroma.

Species No. 102.

A large bacillus found at Middletown. It liquefies gelatine and curdles milk into a soft, faintly alkaline curd, which subsequently digests with a rancid odor. When allowed to ripen cream for a normal length of time, however, it produces no flavor or aroma in the butter.

Species No. 103.

A very common bacterium found both in Middletown and Storrs. It liquefies gelatine but does not curdle milk. It renders milk slightly alkaline and of a slightly dark color. Butter made by means of it develops a slight flavor which is not very good, but not unpleasant. An unpleasant aroma of decay is developed, however, so that the butter is unpleasant.

Species No. 104.

A large micrococcus found in Middletown. It very slowly liquefies gelatine, and curdles milk in eleven days, with no change in reaction. This organism

appears to be extremely variable. It is, however, very common, being, indeed, one of the most common species found in the dairies studied. It has been found in several of the localities mentioned, but appears to vary in its effect upon milk and butter. It usually curdles milk, though occasionally not. Butter made from it sometimes develops a perfectly typical butter aroma, without any flavor,— as fine as that produced by any of the species studied. In other varieties, however, the aroma does not appear to be developed. From the many experiments made I have concluded that it is a widely variable species, varying not only in its general characters, but also in the type of decomposition it produces. The effect of the different varieties upon butter can never be relied upon.

Species No. 105.

A bacillus found at Canton. It does not liquefy gelatine and has no effect upon milk. Butter made from cream inoculated with it develops a slight flavor, which has not an especially pleasant taste, but is not disagreeable. The aroma is noticeable, but very slight, and is not a typical butter aroma. The butter is, in other words, moderately good, but not a first-class product.

Species No. 106.

A bacterium found in Middletown. It does not liquefy gelatine, and has no effect upon milk at any temperature. It produces no flavor and no aroma in the butter.

Species No. 107.

A bacillus found in Middletown. It does not liquefy gelatine or curdle milk at 36°. It renders milk, however, slightly acid, so that it curdles when heated. Butter made from cream ripened by it has a sour clean taste, but with little flavor besides the sour taste. It has a strong aroma, also, which is best developed after about forty-eight hours of ripening. The aroma is strong, but not that of typical butter.

Species No. 108.

A bacterium found in Middletown. It does not liquefy gelatine or curdle milk, though it renders it slightly acid. At 35° it may, in some instances, curdle the milk. Butter made from cream ripened by it is slightly sour, but has a pleasant flavor. It has also an aroma which is decidedly sour, strong, and not typical; it is, indeed, rather yeasty. The flavor is thus good while the aroma is unpleasant.

Species No. 109.

A large micrococcus found in Middletown. It liquefies gelatine, curdles milk with subsequent digestion at 35°, and at 20° digests without curdling. The digested solution is strongly alkaline. Butter made from cream ripened by it is very little affected. There is very slight flavor and aroma, but the butter is quite flat and insipid.

Species No. 110.

A micrococcus found in Middletown. It liquefies gelatine, curdles milk in one day at 36°, and in two days at 20°. It subsequently digests the curd, the resulting liquid being decidedly alkaline. Butter made from cream ripened by it, however, develops no appreciable flavor or aroma, though sometimes there is a slightly bitter taste. The organism is usually neutral in its effect on butter.

Species No. 111.

A bacillus found at Storrs and also in Middletown. It is an extremely common organism. It liquefies gelatine, curdles milk rapidly at both 36° and at 20°, and digests into a watery alkaline solution. Butter made from cream ripened by it is bitter and unpleasant. It has, however, a decided aroma, though not a typical butter aroma.

Species No. 112.

A bacterium found at Storrs. It does not liquefy gelatine or curdle milk either at 20° or at 35°. The milk, however, is rendered acid, and curdles when heated. Butter made from it has a strong, unpleasant aroma, and a sour, unpleasant taste. What appeared to be the same species was found later in the same dairy, but its effect was not so bad, though it did not produce good butter.

Species No. 113.

A micrococcus found at Storrs and at Middletown. It appears to be the most common dairy bacterium found in these localities. It is very variable, ranging in its powers of producing pigment from a snow white to a deep orange. There are all intermediate grades, so that the extreme types are probably of the same species. It liquefies gelatine; curdles milk both at 36° and 20° into a soft curd which is amphoteric. It produces subsequently little or no digestion of the curd. In its effect upon butter it appears to be a favorable species, inasmuch as the flavor that is produced is pleasant, though very slight. It produces, apparently, no aroma. It cannot, therefore, be regarded as especially valuable in butter-making, but its influence is advantageous, so far as it has any at all.

Species No. 114.

A bacillus found at Storrs. It liquefies gelatine and curdles milk after six days. The curd is alkaline and is slowly digested. At 20° it digests without curdling into an alkaline solution. It appears to have absolutely no effect upon butter either in developing flavor or aroma.

Species No. 115.

A bacterium found at Storrs. It liquefies gelatine; curdles milk into a soft curd, which subsequently digests into an alkaline liquid. At 20° there is no curdling, but a digestion occurs without curdling. Its effect upon butter is ordinarily very slight. When cream is ripened for two days at a rather high temperature there is produced, however, a decidedly fine flavor of butter with a good aroma, though neither flavor nor aroma are quite that of typical first-class butter.

Species No. 116.

A large micrococcus found at Storrs. It liquefies gelatine very slowly. It does not curdle milk, but very slowly digests it into a watery liquid which is slightly alkaline. This effect is only produced after about four weeks. When used to ripen cream for a normal length of time it has no effect upon it whatsoever, producing neither flavor nor aroma in the butter.

Species No. 117.

A large micrococcus found at Storrs. It liquefies gelatine slowly. It renders milk quite strongly alkaline, but produces no other change. When used for ripening cream it produces butter with no aroma, and, practically, no flavor. If the cream is over-ripened a flavor and aroma of decay is noticeable.

Species No. 119.

A Sarcina form found at Storrs. It liquefies gelatine and curdles milk in three days at 20° with no change in reaction. Butter made from cream ripened by it is usually without flavor or aroma, but if the ripening be prolonged a flavor is produced, and a pleasant, though not typical, aroma.

Species No. 123.

A bacterium found at Storrs. It liquefies gelatine. It curdles milk rapidly at 36° into a hard alkaline curd which is rapidly digested. Butter made from cream ripened by it develops, when slightly ripened, no flavor and a slight, but unpleasant aroma. If the ripening is continued too long there is developed a flavor and aroma of decay.

Species No. 125.

A bacillus found at Storrs, where it is quite common. It does not liquefy gelatine. It curdles milk after two weeks with an acid reaction. The acid appears first at the bottom, and later spreads throughout. Butter produced by means of it develops a sour, clean taste, pleasant, but rather too sour for good butter. It has, however, no appreciable aroma.

Species No. 126.

A bacillus found at Storrs. It does not liquefy gelatine. It has no effect upon milk, except to develop a slight cheesy aroma. Butter made therefrom develops a strong cheesy aroma and a flavor which is also cheesy, and with a slightly decayed taint which is very noticeable and uniform.

Species No. 129.

A bacterium found at Storrs. It liquefies gelatine slowly. It curdles milk with an alkaline reaction. There is subsequently a slight digestion of the curd, and the liquid is slimy. Butter made from cream ripened by means of it has neither flavor nor aroma; or when more ripened, there is an aroma developed of an unusual character,— not that of butter.

Species No. 130.

A micrococcus found at Storrs. It does not liquefy gelatine. It renders milk acid, but does not curdle it. The milk, however, is in a short time rendered extremly slimy, and capable of being drawn out into long slimy threads. Cream inoculated by it also becomes slimy in an ordinary ripening, but there is no apparent effect upon the flavor or aroma of the butter, the butter appearing to be without either taste or smell.

Species No. 131.

A large bacterium found at Storrs. It liquefies gelatine and curdles milk in two days, with little change in reaction. Very slight digestion is to be seen.

Butter develops a rather sharp, sour (?) taste, which is pleasant and like that of good butter. No aroma is noticed. The butter has thus a good flavor, but without aroma.

Species No. 132.

A micrococcus found at Middletown and at Storrs. It does not liquefy gelatine and has no effect upon milk, except to render it slightly alkaline. Butter made from cream ripened by it has no appreciable flavor or aroma.

Species No. 134.

A bacterium found at Storrs. It does not liquefy gelatine. It renders milk sufficiently acid to curdle when heated, but does not curdle unless heated. Cream inoculated by it has a sharp, penetrating, musty odor and taste, and the butter made therefrom has the same sharp, penetrating taste and aroma. It is not unpleasant, but not typical, and the butter is not first-class.

Species No. 136.

A bacillus found at Storrs, which, while much like No. 97, differs from it in its effect on butter. When cream is ripened by it for two days, there is developed a decidedly good flavor, which is, however, not quite like that of good butter. If less ripened, no flavor develops. There is no aroma.

Species No. 137.

A bacillus found at Storrs. It does not liquefy gelatine. Sometimes it curdles and sometimes it does not curdle milk. There is no change in the reaction of the milk and no digestion. Butter made from cream ripened by it is without either flavor or aroma.

Species No. 138.

A large bacillus found at Middletown. It liquefies gelatine. It curdles milk at 20°, producing a soft curd, which begins to digest almost at once into a colorless, cloudy liquid, which is alkaline. Butter made from cream much ripened by it has a decayed taste and aroma, and if only slightly ripened no appreciable taste or aroma is noticed.

Species No. 139.

A bacillus found in Middletown. It liquefies gelatine and curdles milk in six days without changing the reaction, or occasionally rendering it slightly acid. It develops later a prominent cheesy odor. Cream inoculated with it develops a cheesy odor and taste, and butter made therefrom has the same strong cheesy taste and flavor.

Species No. 143.

A micrococcus found in Middletown. It does not liquefy gelatine, and curdles milk at 20° in from six to nine days. There is no change in the reaction. Butter made from cream ripened by it has no flavor and no aroma, or, at most, a very slight aroma. If the ripening continues too long an aroma and flavor of decay make their appearance.

BACTERIA IN THE DAIRY.

XII.—BACILLUS ACIDI LACTICI AND OTHER ACID ORGANISMS FOUND IN AMERICAN DAIRIES.*

BY W. M. ESTEN, M. S.

I.—BRIEF HISTORY OF EARLY WORK.

In the year 1877 Lister, by means of a capillary pipette to which was attached a screw-head so adjusted that he could force out one-hundredth of a drop of a diluted solution of milk, obtained the first pure culture of a milk-souring organism, which he called *Bacterium lactis*. Lister thus has the honor of being the first to discover and isolate as a pure culture the organism which was subsequently more carefully studied by Hueppe, and named *Bacillus acidi lactici.*

By means of modern bacteriological methods Hueppe was able to make a very thorough investigation of the physiological functions and morphology of this organism, which has been of much value as a standard for the work since done, even up to the present time. Although the characteristics of the organism noted by him do not coincide in every detail with those of the organism recently studied by Günther and Thierfelder and myself, they are all near enough in the essential points to be classed together.

In 1886, Beyer, of Washington, D. C., studied lactic acid fermentations in milk, repeating some of the experiments of Hueppe. The work was incomplete, for he reported studying but one sample of milk, and left out some of the more important features of the analysis for determining the characteristics of this organism. The morphology as described by him is identical with the one recently studied here. The work is not, however, sufficient in detail to determine definitely whether or not he obtained Hueppe's bacillus, though its power to curdle milk in a few hours was rather convincing evidence that he did.

* The account herewith is taken from a more extended report which has been prepared by the author.

After Hueppe, Marpmann, Grotenfelt, and Keyser have isolated milk-souring organisms which agree very well with Hueppe's bacillus. Many other investigators have isolated quite a number of organisms which sour milk, but which are not like *Bacillus acidi lactici*.

Investigators, both in Europe and the United States, having sought to discover Hueppe's bacillus, and frequently failing to do so, though obtaining other milk-souring organisms, have concluded that there are a number of different kinds of organisms which have the power of producing lactic acid from milk sugar and thus precipitating the casein of the milk. This, doubtless, is true, but it does not preclude the fact that there may be one organism which is so universally found in dairies, and is so commonly the cause of milk souring, as to deserve to be regarded as the lactic organism of milk *par excellence*.

The question whether there is one or many organisms which commonly sour milk was discussed pro and con until 1894, nothing definite being determined.

At this time Drs. Günther and Thierfelder published the results of their work.* The character of their work was of the highest order. Their specimens of milk came from a large number of milkmen around the City of Berlin, giving a check to those specimens which might be abnormal, and which if, by chance they were the only ones studied, might give an erroneous conclusion. The method used in the gelatine plate cultures was to put into the prepared gelatine a definite amount of calcium carbonate. This made a somewhat dense medium, but, since the carbonate is very soluble in acids, wherever an acid colony developed it would become surrounded by a clear spot. From a large number of experiments, and the constancy of results, they concluded that there was one organism identical with Lister's *Bacterium lactis* and Hueppe's *Bacillus acidi lactici*, which caused the true ordinary souring of milk.

II.—GENERAL STATUS AND OUTLINE OF FACTS.

In the United States there had been no analytical work on the acid organisms of milk as a distinct work by itself, until October, 1894, when a series of experiments were commenced

* "Bacteriologische und Chemische Untersuchungen über die spontane Milchgerinnung." Aus dem Hygienischen Institut der Universität, Berlin. Archiv für Hygiene.

in the Biological Laboratory of Wesleyan University, to determine whether a miscellaneous collection of species of bacteria caused the common acid fermentation of milk or whether there is a special one which is ubiquitous and like the one found in Europe.

Several organisms were isolated from milk and studied. It was a prominent fact that the majority of organisms were anaerobes or facultative anaerobes. These were discarded as many others have done in studying milk organisms because they do not grow on the surface of culture media, or if they do, grow very scantily. The territory studied was in the city of Middletown and a section of Northern Rhode Island. Some species were found to be identical in both localities, but nothing definite was determined. Some species curdled milk; others made it acid, without curdling. There was this striking fact that there was no one organism in either place which seemed to produce a typical sour milk.

In the early part of the present year (1896) a second series of experiments were conducted, in which it was considered advisable to make a study of milk in a much wider territory. In these experiments the facultative anaerobes were picked out and studied. Some of these were found to be very strongly acid when grown in blue-litmus gelatine, which was especially prepared for the study of the acid organisms.

The widest extent of territory from which samples of milk have been received is from Ohio to Massachusetts and from Maine to Pennsylvania.

Through the kindness of students I have been enabled to receive these samples of milk from many localities and a wide extent of territory. The definite localities are Elyria, Ohio; Buffalo, Western; Wellsboro, Northern; and two places on Long Island, Southern New York; Mahanoy City, Pennsylvania; Turner's Falls, Northern; and Uxbridge, Southern Massachusetts; Mt. Desert Island and North Wayne, Maine; Plymouth, New Hampshire; Eastford, Norwich, Higganum and Middletown, Connecticut; Glendale and Oakland, Rhode Island. Single samples have been received from Wellsboro and Long Island, New York; Mahanoy City, Pennsylvania; Turner's Falls, Massachusetts; North Wayne, Maine; Plymouth, New Hampshire; Norwich, Higganum and Eastford, Connecticut. From the other localities from two to five

specimens have been received from the same place. The Rhode Island locality was very carefully studied. Milk was collected from twelve dairies in this section, in as fresh a condition as possible. In four samples it was taken direct from the teat. From most of the dairies many samples have been received, some of mixed milk, others from one cow.

Thirty dairies have furnished fifty-three samples of milk, from which one hundred and eleven colonies have been isolated. Thirty-four of these were discarded as not producing acid, or as nearly anaerobic. Of the seventy-seven studied, forty-seven of them appeared to be the same species. Although the analysis of these forty-seven severally is not identical in some of the minor details, yet in the most important distinctions they agree. The distinctive character of this species is the power of curdling milk in a very short space of time. The actual limit has not been determined; but sterile milk inoculated with a small amount of culture, placed at thirty-five degrees centigrade, was examined in twelve hours and found to be thoroughly curdled. At the normal room temperature it curdles milk in from sixteen to thirty-six hours.

Along with this species, and supposed to be the same when first picked out, were ten others, which in all the culture tests seemed to be identical in character with the forty-seven, with the exception that they did not curdle milk, although they did make it acid. Some rendered milk strongly acid, others weakly acid. These facts seem to suggest that they are the same species as the forty-seven, but that these ten had lost the power of curdling milk.

Of the twenty remaining organisms ten were aerobes and produced acid sufficient to curdle milk. Three of these were the same species, one coming from Ohio, and the other two from Massachusetts. These aerobic acid organisms were taken from six samples. The forty-seven facultative anaerobic acid curdling specimens, which were alike, were found in the fifty-three samples of milk studied.

III.—TECHNIQUE OF EXPERIMENTS AND ANALYSIS OF THE PRINCIPAL ORGANISM.

Ordinary peptone-gelatine was prepared, to which was added 3 per cent. of milk sugar and dry blue litmus, in the proportion of one to thirty parts of the culture medium. The gelatine

solution was neutralized so that it was slightly acid to phenolthphaline. Into this blue gelatine a small amount of diluted souring milk was inoculated, in the usual manner. After three or four days small red spots appeared where the acid bacteria developed. This simplifies the work very much, since the acid and alkaline organisms are differentiated at once. All of the culture media were prepared with three per cent. of milk sugar.

Fresh milk was allowed to stand until it commenced to curdle. At this stage there would be more of the typical acid organisms than at any previous or subsequent time in the changes of the milk. The dilutions were made with a platinum loop full of milk in five centimeters of sterile water. Those plates in which liquefiers were present prevented the discovery of the slow-growing acid organisms. When but a few or no liquefiers were present, in three or four days there would appear below the surface bright red spots, which showed very clearly in the surrounding blue. Not many acid colonies grew on the surface of the gelatine. The most abundant on the surface were moulds, yeasts, neutral and alkaline bacteria. The first sample of milk from one dairy had nearly a pure culture of an alkaline liquefier, although the milk was acid in reaction. The next sample from the same place, collected two weeks later, had not a single liquefier, but a nearly pure culture of one organism, which appears to be the one so commonly present in nearly all the samples, and agrees so closely with the one isolated by Günther and Thierfelder that it is called *Bacillus acidi lactici* of Hueppe.

PHYSIOLOGICAL AND MORPHOLOGICAL CHARACTERS OF BACILLUS ACIDI LACTICI AS FOUND IN MILK IN THE UNITED STATES.

I.—BLUE LITMUS GELATINE.

It requires from two to three days to develop a typical colony. Under a low power of the microscope, one inch objective, a small colony appears, surrounded by an intense red halo. The colony appears to be covered with short stumpy spines, which give it the appearance of a chestnut burr, and from which it has been named the *burr colony*. Under a high power these spines are found to be granular processes which extend

for a short distance into the surrounding medium. In some instances there will be a dark centre surrounded by a lighter rim. Their size is always less than one millimeter. The more common appearance under the microscope is a dark-colored, spiny, slightly yellowish colony, homogenous in density. They never appear to grow on the surface, but, in some cases, very near the surface, with a thin layer of gelatine above it raised by the growth of the colony.

II.—ORDINARY GELATINE.

There is produced in this medium a small circular colony which is finely granular; pearly white by reflected light, and slightly yellowish by transmitted light. The growth is very slow.

MORPHOLOGY.

In bouillon there appear short plump rods, many of them in figure 8's, some in chains of three to six in number. To make these, a rod, after lengthening, partially breaks up into five or six. The common method of multiplication is, for a rod to lengthen and divide in the middle, the connection between the two remaining for some time. Average size is 1.2μ long by .7μ wide.*

MOTILITY.

They are never motile.

TEMPERATURE.

The growth is very rapid in milk at temperatures from 28° to 37½° C. On agar-agar they do not grow so rapidly at a high temperature, and even, in some instances, do not grow on the surface of agar-agar at 37½° C.

RELATION TO AIR.

They grow more vigorously out of contact with the air, under mica plates producing more acid than in free gelatine.

GELATINE STAB CULTURES.

Growth entirely below surface along the needle track, which is abundant, beady, rough, and densely white.

AGAR-AGAR TUBES.

It grows on the surface of agar-agar very scantily, not more than one or two mm. wide, in a very thin layer. If held to the

* μ equals $\frac{1}{25,000}$ of an inch.

light, at the proper angle, spectral colors will be observed. The stab growth in agar-agar is more abundant, and affords the only method of keeping it alive, because it soon dries up the surface and dies.

CULTURE ON POTATO.

Grows on potato very sparingly, in a thin, pearly, white layer, sometimes scarcely visible.

BOUILLON.

In milk-sugar bouillon the liquid becomes densely turbid. In a week it gradually settles, giving a light gray sediment in a clear liquid. No scum or gas production is observed. Sometimes a light-colored ring is formed on the glass at top of liquid.

STERILIZED MILK.

Cultures inoculated into sterile milk at 20° C. curdle it in twenty-four hours. At 35° C. it curdles milk in less than twelve hours. The curd is homogenous and of jelly consistency, so that the tube can be inverted without displacing the contents. The milk shrinks in curdling, leaving a concave surface on the top of the milk. After the curdling the milk undergoes no further visible change. A few drops of clear whey separates on top of the milk. The curd and clear liquid are intensely acid. No evidence of gas production or odor present.

GENERAL REMARKS.

It does not appear to produce spores. Hueppe describes it as a spore-forming species, but this appears to be an error. In staining specimens of these organisms the centers quite frequently remain unstained, which might lead to the misconception that spores are present. The unstained portion does not show a glistening appearance, which is an optical effect produced by spores.

The organism is quite difficult to cultivate. It lives but a short time on the surface of agar-agar, grows entirely below surface of gelatine, and very slowly in culture media at ordinary room temperatures. Its home seems to be milk, where it flourishes to the best advantage at a temperature nearly that of the heat of the body.

The habitat of this organism is a problem which is interesting for further investigation. A few experiments were tried to determine whether it came from hay dust or some other

source. Hay and hay dust were collected from three barns and put into sterile milk and left to undergo fermentation. The changes were very tardy in making their appearance. In a few days the milk curdled and gelatine plate cultures were made from the milk tubes. There were several kinds of alkaline and acid organisms, but none that resembled *Bacillus acidi lactici*. There was present a very vigorously growing, strongly acid-producing organism.

Four experiments were tried with milk direct from the cow's teat. The first experiment from a cow in Rhode Island was very remarkable. The milk collected was the first drawn, in which it is supposed that the germs are most abundant. The milk remained in a warm room for twenty-two days before it curdled, and the organisms then obtained from it were not acid.

The second experiment from the same cow gave a nearly pure culture of *Bacillus acidi lactici*. Two experiments were tried in the same manner with the milk of a single cow in Massachusetts, both of which gave a majority of *Bacillus acidi lactici* colonies. From these insufficient data is suggested the possibility that *Bacillus acidi lactici* comes from the cow in the milk duct, since its maximum temperature of growth is about that of the body temperature.

There were three species of organisms so closely allied to *Bacillus acidi lactici* that I consider them varieties of that organism. The first was found at Sagaponack and Miller's Place, New York, and Glendale, Rhode Island. The points in which it differs from *Bacillus acidi lactici* are, that it does not grow at 35° C., and though it renders milk strongly acid it does not curdle it. The second, found at Glendale, Rhode Island, was almost identical with the first, except that it rendered milk only slightly acid. The third, found at Uxbridge, Massachusetts, was like the second, but grew at 37½° C.

Many of the specimens of milk yielded a nearly pure culture of *Bacillus acidi lactici*. When the milk was set aside to sour, many of the alkaline species disappeared as the lactic acid increased in strength. On the other hand, some specimens of milk had so many liquefiers that it was difficult to obtain from the gelatine plate cultures the slowly growing *Bacillus acidi lactici*, which doubtless soured the milk and made it acid, but did not have time to develop before the gelatine was liquefied.

AEROBIC ACID CURDLING ORGANISMS.

Ten different species were isolated, which will be more fully described in a later publication. Nearly all of these were abundant gas producers, both in gelatine and milk. When these were inoculated into sterile milk, they commonly caused much separation of whey and digestion of the curd. A few curdled milk only when grown at 35° C. One species was found in three places in Ohio, and two places in Massachusetts. Some of them produced a typical curdling of milk without subsequent digestion.

CONCLUSION.

It is necessary to repeat more fully the experiments in the territory covered and to obtain data from other places before a valuable, scientific conclusion can be drawn. It is of course possible that the forty-seven organisms isolated are a collection of many species, but the evidence from the data obtained leaves no doubt in my mind that they are the same species.

Milk from thirty widely separated localities in New York, Pennsylvania, Ohio, Maine, New Hampshire, Massachusetts, Rhode Island and Connecticut, yielded, with two exceptions, apparently the same organism. This fact throws the weight of evidence on the side of the belief that one organism universally exists in the territory studied, which produces the ordinary souring and curdling of milk. This organism seems to be identical in every particular with that of Günther and Thierfelder, who concluded that their organism was the same as Lister's *Bacterium lactis* and Hueppe's *Bacillus acidi lactici.*

A STUDY OF RATIONS FED TO MILCH COWS IN CONNECTICUT.

REPORTED BY W. O. ATWATER AND C. S. PHELPS.

The study of rations fed to milch cows on dairy farms in this State, which was begun in the winter of 1892–93, has been repeated each winter since.

Detailed descriptions of the work of the first three winters have been given in the Station publications.* The results of the fourth winter's work (1895–96) are here reported.

Each herd was selected after a personal inspection, or after sufficient correspondence to satisfy ourselves of its fitness for the proposed test, and a representative of the Station was present during the whole period of each test and personally attended to the details of the experiment, such as weighing the feeding stuffs, and taking samples for analyses, and weighing, sampling and determining the butter-fat in the milk. This work was faithfully performed by Mr. C. B. Lane, at that time Assistant Agriculturist to the Station.

In the first winter's work (1892–93), which was regarded as preliminary to an investigation that might extend over a series of years, it was thought better to examine a relatively large number of herds, each during a short period, than to make the periods longer and the number of herds less. Sixteen herds were visited and a five-days' test was made of each.

In the second winter's work (1893–94) six different herds were visited, and in four cases the time of study of the management and products of each herd was extended to twelve days. The analyses of the feeding stuffs were made at once, and the weights of nutrients in the rations as fed were calculated. In three instances other rations were thereupon suggested by us as being better than the ones that had been used. The owners gradually changed the food to the ration thus proposed, and after an interval of four weeks from the close of the

* Reports of this Station for 1893, pp. 69–115; 1894, pp. 26–56; and 1895, pp. 40–76. Bulletin 13 of this Station. Reports of the Connecticut Board of Agriculture, 1893, pp. 182–199; and 1894, pp. 131–146.

first test, another twelve-days' test was made of the same herd. A comparison was thus made of the yields of milk and butter-fat with the two different rations.

During the third winter (1894–95) four herds were visited, each herd being under observation for twelve days at two different periods in the same manner as the three herds studied in 1893–94, except that there was only a two-weeks' interval between the two tests on the same herd.

HERD TESTS DURING 1895–96.

During the fourth winter (1895–96) two herds were studied in a similar way, except that in the one case the ration with much larger quantity of protein, and a much narrower nutritive ratio than usual, was used. Samples of the different feeding stuffs used in the tests were taken early in each test and sent to the laboratory for analysis.

In the earlier tests, as soon as it was possible to obtain the results of the analyses, the proportions of nutrients in the ration fed was calculated, and suggestions were made for changes in the ration. After changes had been made and the animals had been upon the new ration for two weeks or longer, the herd was again visited and a new twelve-days' test was made. In the tests during 1895–96 the Station representative stayed at the farm and made the change of ration. In these cases only nine days intervened between the two tests on the same herd, and it became necessary to calculate the first ration from average tables of analyses, as a basis for formulating a new ration. This was done with the idea that it would be best to have the Station make the change of feed. The time proved rather short, however, for making the change, and the present winter (1896–97) we have gone back to the plan of allowing two weeks between tests on the same herd.

The chief points upon which information was obtained were:

Number of animals in the herd.—In considering the number of animals, only those which came into the test were included. Usually these were all of the cows on the farm which were in milk at the time of the test, except those which were nearly dry.

Breed, age, and approximate weight of each cow.—The breed and age were obtained as accurately as possible from the owner. Since it was not practicable to take to the farm scales large

enough on which to weigh the cows, the weights were estimated. This estimate was made in each case by the Station representative, and it is thought that the errors of judgment may run more or less equally through all the herds examined.

Number of months since last calf.—In most cases the time at which the cow dropped her last calf was known.

Number of months till due to calve.—There was, of course, more or less uncertainty in this regard.

Weights of milk-flow for the twelve days of the test.—The milk of each cow at each milking was weighed as soon as milked, to the nearest tenth of a pound, by the Station representative.

Percentages and amounts of butter-fat in the milk.—A sample of the milk of each cow, night and morning, was taken, and from the combined sample a determination of the quantity of butter-fat was made. The Babcock method of fat determination was employed. From the percentages of butter-fat in the milk, and the total weights of the milk, the daily yields of butter-fat were obtained.

Kinds and weights of foods used.—The feeder was requested to use the same kinds and amounts of feeding stuffs during the test period as he had previously been using. The quantity for each animal was weighed by the Station representative just before feeding. Any portions of the food left uneaten by the cows were carefully weighed, and due allowance was made for these uneaten residues in estimating the amounts daily eaten. During the test, usually on the third day, samples of each feeding stuff used were carefully taken and at once sent to the laboratory for analysis. From the results of the analyses and the weights fed, the total nutrients (protein, fat, nitrogen-free extract, and fiber) fed each day were calculated. By the use of digestion coefficients, estimates were made of the weights of digestible nutrients in each day's ration.

The names and post-office addresses of the owners of the herds studied by the Station during the four winters, 1892–93, 1893–94, 1894–95, and 1895–96, are given beyond, on page 64, together with the dates at which the Station representative was at the farm. At the left, in the first column of figures, is a reference number for each test. In the remaining tables, and

in the discussion, the herds entering into the tests and the rations fed are designated by these reference numbers.

The experiments of the winter of 1895–96, which are here reported, were made with herds of:

Mr. Simon Brewster, Jewett City. Test No. 35, December 3–14; and test No. 37, Dec. 22–Jan. 2.

Mr. H. R. Hayden, East Hartford. Test No. 36, Feb. 11–22; and test No. 38, March 6–17.

EXPLANATIONS.

The following brief explanation of nutrients of feeding stuffs and their uses is reprinted from the Report of this Station for 1894:

Uses of food.—The two chief uses of food are to form the materials of the body and make up its wastes, and to yield energy in the form of heat to keep the body warm and in the form of muscular and other power for the work it has to do. The principal tissue-formers of the food are the protein or nitrogenous compounds. They build up and repair the nitrogenous materials, as the muscle and bone, and supply the albuminoids of blood, milk, and other fluids. The chief fuel ingredients of the food are the carbohydrates (such as sugar, starch, etc.,) and fat. These are either consumed in the body or stored as fat to be used as occasion demands.

Fuel value.—The value of food as fuel may be measured in terms of potential energy. The unit commonly used is the calorie. One calorie is the amount of heat necessary to raise the temperature of a pound of water about four degrees Fahrenheit.* From experiment it has been found that a pound of protein or carbohydrates yields, when burned, about 1,860 calories of fuel value, and that a pound of fat yields about 4,220 calories.

Nutritive ratio.—There is a very important relation between the amounts of protein (flesh formers) and the amounts of fuel constituents of a food. This relation is expressed by the nutritive ratio. The fuel value of fat is about two and one-fourth times that of the carbohydrates and the protein, hence it happens that if the sum of the digestible carbohydrates and two and one-fourth times the digestible fat of a ration is divided by the amount of digestible protein in the ration, the quotient gives what is called the nutritive ratio.

Wide ration.—Narrow ration.—If the quantities of digestible fat and carbohydrates are large relative to the protein, the nutritive ratio will be a large number and the ration is called a "wide ration;" if the quantities of digestible fat and carbohydrates are relatively small, the quotient is a small number and the ration is a "narrow" one. A ration where the nutritive ratio is much more than 1:6 may be called a "wide ration;" if much less, it may be called a "narrow ration."

Nearly all of the grasses and hays have a wide nutritive ratio, and the same is true of corn and many of its products, such as meal and hominy chops. The use of such feeding stuffs will tend to make a ration wide. The legumes, such

* The calorie is exactly the heat necessary to raise the temperature of one kilogram of water one degree centigrade. It is equivalent to 1.5 foot tons, or to the mechanical power that would lift 1.5 tons one foot.

as clover, peas, vetch, etc., and many of the products of milling and food manufacture are relatively rich in protein, and hence have narrow nutritive ratios.

The measure of the size of a ration.—In order that a ration may be complete, there must be enough digestible protein supplied in the food to build new tissues (bone, muscle, milk, etc.,) and repair the wastes of the body, and sufficient digestible fat and carbohydrates to furnish heat and muscular energy. As the chief function of the fat and carbohydrates is to serve as fuel, it is more important that enough of these should be provided to meet the needs of the animal than that they should be supplied in definite relative proportions. It is, therefore, possible to form a very good idea of the nutrients furnished in a ration, and to measure its size by the quantity of digestible protein or flesh-formers which it contains, and the fuel value of its digestible constituents.

RESULTS OF THE EXPERIMENTS.

Tables 1 to 8 inclusive contain the results of the observations and studies of the different herds.

The following abbreviations are used in the tables:

Abbreviations used in report of rations fed to milch cows.

G.=Grade. Hol.=Holstein. Jy.=Jersey. Nat.=Native.

The tables are alike in arrangement, and a description of one will serve for all. Each table contains the condensed results of a single test. Table 1, for instance, gives the statistics for herd test No. 35.

The first part of the upper table gives a reference number of each animal, its breed, age, weight, and number of months since last calf. The smallest daily milk flow, the greatest daily milk flow, and the average daily yield of milk for the period of the test are given in the next three columns. In the three following columns are given the lowest, highest, and average percentages of fat found in the daily milk of each cow for the period. The last named figures were obtained by adding together the several daily determinations and taking the average as representing the whole period, hence this actual average is not always half way between the highest and the lowest. The yield of fat is given in the last three columns of the first or upper part of the table. The minimum and maximum yields of fats were obtained by multiplying each day's milk by its percentage of fat; the lowest number thus obtained gives the minimum daily yield of fat, and the largest the maximum yield of fat. It is to be noted that these numbers are not always the same as would have been obtained by multiplying the minimum and maximum daily milk flow by the minimum and maximum percentages of fat.

The lower part of each table gives the kinds and amounts of the different feeding stuffs eaten per day, and the weights of the digestible nutrients (protein, fat and carbohydrates) which they were estimated to furnish. The weights of foods and nutrients are calculated per 1,000 pounds live weight and also "per average weight" of each herd. These last figures, which are given in the last five columns of the table, represent the average amount actually fed per animal.

All of the different feeding stuffs used in these rations were analyzed. From the weights of the different feeding stuffs, the results of the analyses, and the digestion coefficients given in the following table, the weights of digestible nutrients were calculated in the usual way. The fuel value, or potential energy furnished by the different foods, was obtained by multiplying the number of pounds of protein and of carbohydrates by 1,860, and the number of pounds of fat by 4,220, and taking the sum of these three products as the number of calories of potential energy in the materials.

The rations fed in 1895–96 are summarized with those of the three previous winters in table 5.

DIGESTIBILITY OF FEEDING STUFFS.

We have had frequent occasion to insist in the publications of this Station that the estimates of the quantities of nutrients in these rations, and in feeding stuffs generally, are not absolutely accurate unless the feeding stuffs themselves are accurately analyzed, since materials of the same kind vary considerably in composition and the figures ordinarily printed in tables of composition represent only general averages. The same is true of the digestibility of a given amount of protein in a feeding stuff or a ration, a larger or smaller portion may be digested in a given case. The proportion digested will depend upon the digestive powers of the animal and the character of the feeding stuff. The same is true of the fats and carbohydrates. The proportions of each ingredient which are supposed to be actually digested are commonly expressed in percentages, and in that form are designated as coefficients of digestibility.*

* For explanations of these subjects, see articles on digestion experiments, and especially articles on the digestibility of feeding stuffs and the calculation of rations in the Report for 1893, pages 156 and 168.

The coefficients of digestibility used here are given in the following table. They are practically the same as those used in previous reports. They are based upon the results of digestion experiments with domestic animals. Where such experiments have been made in this country, in sufficient number to give reliable results, these are used for the coefficients. In other cases the results of European (and especially German) experiments have been drawn upon for the purpose.

Coefficients of digestibility employed in calculating the digestible nutrients in the different feeding stuffs used in these rations.

Kind.	Protein.	Fat.	Carbohydrates.	
			Nitrogen-free Extract.	Fiber.
	%	%	%	%
Wheat bran,	78*	76*	72*	33†
Linseed meal,	86†	90†	80†	50†
Cotton seed meal,	89*	100*	68*	33†
Wheat middlings,	79*	85*	83*	33†
Corn meal,	76†	92†	87†	58†
Gluten meal,	87*	88*	91*	33†
Good quality hay,	54*	54*	63*	55*
Poor quality hay,	45*	28*	60*	46*
Clover hay,	61*	49*	65*	46*
Oat hay,	53*	61*	52*	43*
Corn stalks (stover),	52*	52*	64*	66*
Potatoes,	44*	13*	91*	—

* From results of American digestion experiments.
† From results of German digestion experiments.

In order to show the range of variation from day to day in the feeding of the same herd, the minimum and maximum daily rations per 1,000 pounds live weight and per average weight of each herd are appended in the tables. The size of the ration is here measured by the fuel value of the digestible nutrients (protein, fat, etc.). A ration which has a large fuel value may have a small amount of a given kind of food or a given kind of nutrients. Hence it sometimes happens that the minimum of one of the nutrients furnished by a certain kind of feeding stuff in a given ration may be greater than the average of the nutrients in that ration. The same may happen conversely, in the case of the maximum.

TABLE I.

Dairy Test No. 35.—Statistics of herd from December 3 to December 14, 1895.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow. Min.	Daily Milk Flow. Max.	Daily Milk Flow. Avg.	Daily Percentage of Fat. Min.	Daily Percentage of Fat. Max.	Daily Percentage of Fat. Avg.	Daily Yield of Fat. Min.	Daily Yield of Fat. Max.	Daily Yield of Fat. Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	Native, -	7	800	2	14.4	16.2	**15.1**	4.7	5.3	**5.1**	.71	.83	**.77**
2	Native, -	7	750	14	10.5	12.7	**11.6**	3.9	5.2	**4.4**	.44	.61	**.51**
3	G. Jy., -	11	765	1	25.2	29.2	**27.4**	2.9	3.6	**3.2**	.77	.96	**.88**
4	G. Jy., -	11	850	3	12.9	14.8	**14.0**	3.4	5.8	**4.3**	.47	.80	**.60**
5	G. Jy., -	10	825	1	16.3	22.3	**20.6**	4.1	6.4	**4.9**	.83	1.63	**1.01**
6	G. Jy., -	10	725	3	13.7	15.4	**14.4**	3.5	5.1	**3.9**	.51	.72	**.56**
7	G. Jy., -	10	675	2	12.1	16.6	**15.1**	3.8	6.3	**4.9**	.58	.98	**.74**
8	Native, -	4	700	2	19.1	21.7	**20.3**	3.0	3.7	**3.3**	.61	.75	**.67**
9	Native, -	12	750	8	7.9	11.6	**9.8**	4.6	5.9	**5.3**	.36	.58	**.52**
10	Native, -	8	775	4	16.6	18.6	**17.5**	3.8	4.9	**4.4**	.65	.85	**.77**
11	Native, -	7	800	4	17.5	19.0	**18.4**	3.8	4.6	**4.2**	.71	.87	**.77**
	Herd avg., -	—	775	—	—	—	**16.7**	—	—	**4.3**	—	—	**.72**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (775 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value.	Per Average Weight (775 Lbs.) of Herd. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Corn meal, - -	4.1	.29	.20	2.54	—	—	3.2	.22	.15	1.97	—
Wheat bran, - -	2.2	.30	.08	.93	—	—	1.7	.23	.06	.72	—
Wheat middlings, -	3.1	.42	.10	1.67	—	—	2.4	.33	.08	1.29	—
Total conc. food, -	9.4	1.01	.38	5.14	5.9	13050	7.3	.78	.29	3.98	10050
Oat hay, - -	8.7	.36	.19	3.14	—	—	6.8	.28	.15	2.43	—
Corn stover, - -	14.1	.47	.15	6.71	—	—	10.9	.36	.12	5.20	—
Total coarse food, -	22.8	.83	.34	9.85	12.8	21300	17.7	.64	.27	7.63	16550
Total food, -	**32.2**	**1.84**	**.72**	**14.99**	**9.0**	**34350**	**25.0**	**1.42**	**.56**	**11.61**	**26600**
Minimum per Day.											
Concentrated food,	9.2	.99	.38	5.00	5.9	12750	7.1	.77	.30	3.88	9900
Coarse food, - -	18.4	.67	.30	6.70	11.0	14950	14.3	.52	.23	5.19	11600
Total food, -	27.6	1.66	.68	11.70	8.0	27700	21.4	1.29	.53	9.07	21500
Maximum per Day.											
Concentrated food,	8.7	.96	.35	4.71	5.7	12050	6.7	.74	.27	3.65	9300
Coarse food, - -	26.1	.96	.39	11.26	12.6	24350	20.2	.74	.30	8.73	18900
Total food, -	34.8	1.92	.74	15.97	9.2	36400	26.9	1.48	.57	12.38	28200

TABLE 2.

Dairy Test No. 36.—Statistics of herd from February 11 to February 22, 1896.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow.			Daily Percentage of Fat.			Daily Yield of Fat.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy., -	6	750	—	13.7	15.9	**14.6**	5.7	6.5	**6.2**	.82	.96	**.90**
2	G. Jy., -	3	675	—	7.8	9.9	**9.1**	5.0	5.9	**5.4**	.39	.54	**.49**
3	G. Hol., -	6	700	—	12.3	13.9	**13.1**	5.4	6.4	**5.9**	.66	.81	**.77**
4	Native, -	5	750	—	11.8	13.2	**12.6**	5.4	5.8	**5.5**	.66	.74	**.69**
5	G. Jy., -	10	925	—	14.4	18.9	**17.4**	4.5	5.9	**5.4**	.65	1.17	**.94**
6	G. Jy., -	6	750	—	21.8	24.0	**22.9**	4.8	6.4	**5.1**	1.07	1.50	**1.16**
7	Native, -	8	825	—	24.4	27.0	**26.2**	4.1	5.0	**4.6**	1.05	1.35	**1.20**
8	G. Jy., -	2	750	—	10.0	11.1	**10.5**	4.4	5.4	**5.1**	.44	.57	**.54**
9	G. Jy., -	7	725	—	22.0	24.0	**22.8**	3.7	4.8	**4.4**	.84	1.15	**1.00**
10	G. Jy., -	2	650	—	7.3	10.9	**10.0**	5.0	5.8	**5.4**	.39	.61	**.54**
11	Native, -	6	725	—	16.7	19.1	**17.9**	4.7	5.9	**5.5**	.85	1.12	**.98**
12	G. Jy., -	7	750	—	16.2	18.5	**17.6**	4.5	5.2	**5.0**	.79	.94	**.88**
13	G. Jy., -	6	725	—	19.9	23.3	**21.7**	4.9	5.5	**5.3**	.98	1.21	**1.15**
14	G. Hol., -	9	750	—	19.8	22.6	**21.1**	4.1	5.8	**4.7**	.81	1.24	**.99**
	Herd avg.,	—	**750**	—	—	—	**17.0**	—	—	**5.3**	—	—	**.87**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (750 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight.						Per Average Weight (750 Lbs.) of Herd.				
	Average Fed per Day.	Digestible Nutrients and Fuel Value.					Average Fed per Day.	Digestible Nutrients and Fuel Value.			
		Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.		Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Grain,* - -	12.6	2.36	.54	5.84	3.0	17500	9.4	1.77	.40	4.38	13150
Hay, 1st quality, -	6.6	.23	.08	3.12	—	—	5.0	.17	.06	2.34	—
Hay, 2d quality, -	6.6	.35	.04	2.69	—	—	5.0	.26	.03	2.02	—
Stover, - - -	9.5	.16	.06	3.84	—	—	7.1	.12	.04	2.88	—
Potatoes, - -	2.7	.03	-	.45	—	—	2.0	.02	-	.34	—
Total coarse food, -	25.4	.77	.18	10.10	13.7	21000	19.1	.57	.13	7.58	15700
Total food, -	**38.0**	**3.13**	**.72**	**15.94**	**5.6**	**38500**	**28.5**	**2.34**	**.53**	**11.96**	**28850**
Minimum per Day.											
Concentrated food,	11.7	2.18	.50	5.42	3.0	16250	8.8	1.64	.37	4.06	12150
Coarse food, - -	24.8	.72	.17	9.85	14.2	20350	18.6	.54	.13	7.39	15300
Total food, -	36.5	2.90	.67	15.27	5.8	36600	27.4	2.18	.50	11.45	27450
Maximum per Day.											
Concentrated food,	12.3	2.30	.53	5.70	3.0	17150	9.2	1.73	.39	4.28	12850
Coarse food, - -	28.8	.88	.20	11.55	14.5	23950	21.6	.66	.15	8.66	17950
Total food, -	41.1	3.18	.73	17.25	6.0	41100	30.8	2.39	.54	12.94	30800

* The grain used was mixed as follows: Wheat bran, 3.7 lbs.; linseed meal, 1.6 lbs.; corn meal, 1.6 lbs.; Buffalo gluten feed, 2.5 lbs. Total, 9.4 lbs. per day per average weight of herd.

Table 3.

Dairy Test No. 37.—Statistics of herd from December 22, 1895, to January 2, 1896.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow. Min.	Daily Milk Flow. Max.	Daily Milk Flow. Avg.	Daily Percentage of Fat. Min.	Daily Percentage of Fat. Max.	Daily Percentage of Fat. Avg.	Daily Yield of Fat. Min.	Daily Yield of Fat. Max.	Daily Yield of Fat. Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	Native, -	7	800	2	16.0	18.0	**17.0**	4.7	5.0	**4.9**	.77	.89	**.83**
2	Native, -	7	750	14	11.6	12.5	**12.0**	3.8	4.5	**4.3**	.46	.54	**.52**
3	G. Jy., -	11	765	1	26.4	29.0	**27.2**	3.0	3.9	**3.4**	.84	1.03	**.93**
4	G. Jy., -	11	850	3	12.6	14.5	**14.0**	3.2	5.4	**4.6**	.43	.78	**.64**
5	G. Jy., -	10	825	1	17.5	23.9	**19.9**	3.5	8.1	**5.1**	.62	1.94	**1.02**
6	G. Jy., -	10	725	3	13.9	17.1	**15.0**	3.6	4.8	**4.3**	.55	.82	**.64**
7	G. Jy., -	10	675	2	14.5	17.7	**16.1**	3.8	5.9	**4.7**	.55	1.04	**.76**
8	Native, -	4	700	2	20.3	22.4	**21.2**	3.0	4.3	**3.7**	.65	.90	**.78**
9	Native, -	12	750	8	8.4	12.0	**10.9**	4.2	5.8	**5.1**	.43	.68	**.56**
10	Native, -	8	775	4	16.7	20.0	**18.5**	3.6	4.8	**4.4**	.63	.92	**.81**
11	Native, -	7	800	4	19.4	20.7	**20.0**	3.9	5.3	**4.3**	.78	1.06	**.86**
	Herd avg.,	—	**775**	—	—	—	**17.4**	—	—	**4.4**	—	—	**.77**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (775 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight. Average Fed per Day.	Per 1000 Lbs. Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value.	Per Average Weight (775 Lbs.) of Herd. Average Fed per Day.	Per Average Weight Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Gluten meal, - -	4.0	1.15	.27	1.69	—	—	3.1	.89	.21	1.31	—
Wheat bran, - -	2.0	.27	.07	.85	—	—	1.5	.21	.05	.66	—
Wheat middlings, -	2.8	.37	.09	1.52	—	—	2.2	.29	.07	1.18	—
Total conc. food, -	8.8	1.79	.43	4.06	2.8	12700	6.8	1.39	.33	3.15	9850
Clover hay, - -	8.3	.74	.09	3.30	—	—	6.4	.57	.07	2.55	—
Corn stover, - -	11.9	.40	.12	5.66	—	—	9.2	.31	.09	4.39	—
Total coarse food, -	20.2	1.14	.21	8.96	8.2	19700	15.6	.88	.16	6.94	15200
Total food, -	**29.0**	**2.93**	**.64**	**13.02**	**4.9**	**32400**	**22.4**	**2.27**	**.49**	**10.09**	**25050**
Minimum per Day.											
Concentrated food,	8.7	1.78	.43	4.00	2.8	12600	6.8	1.38	.33	3.10	9700
Coarse food, - -	19.6	1.09	.20	8.73	8.4	19100	15.2	.84	.15	6.76	14750
Total food, -	28.3	2.87	.63	12.73	1.49	31700	22.0	2.22	.48	9.86	24450
Maximum per Day.											
Concentrated food,	8.8	1.80	.43	4.08	2.8	12750	6.8	1.39	.33	3.16	9850
Coarse food, - -	21.2	1.21	.23	9.42	8.2	20750	16.4	.94	.18	7.30	16100
Total food, -	30.0	3.01	.66	13.50	5.0	33500	23.2	2.33	.51	10.46	25950

TABLE 4.

Dairy Test No. 38.—Statistics of herd from March 6 to March 17, 1896.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow. Min.	Max.	Avg.	Daily Percentage of Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy., -	6	750	—	14.0	15.8	**15.1**	6.2	6.7	**6.4**	.91	1.01	**.97**
2	G. Jy., -	3	675	—	7.8	8.6	**8.3**	5.8	6.2	**6.1**	.48	.53	**.51**
3	G. Hol., -	6	700	—	12.0	13.2	**12.7**	5.6	6.5	**6.1**	.68	.84	**.77**
4	Native, -	5	750	—	12.5	13.5	**12.9**	5.6	6.3	**5.8**	.70	.81	**.75**
5	G. Jy., -	10	925	—	16.4	19.3	**17.8**	5.2	6.3	**5.8**	.93	1.14	**1.03**
6	G. Jy., -	6	750	—	22.1	24.2	**23.3**	4.7	5.9	**5.2**	1.04	1.39	**1.20**
7	Native, -	8	825	—	25.1	27.5	**26.5**	4.5	5.4	**4.8**	1.15	1.47	**1.27**
8	G. Jy., -	2	750	—	10.0	10.8	**10.5**	5.2	5.8	**5.4**	.52	.60	**.57**
9	G. Jy., -	7	725	—	21.9	24.5	**23.1**	4.1	5.0	**4.6**	.90	1.24	**1.06**
10	G. Jy., -	2	650	—	9.4	11.1	**10.5**	5.3	6.2	**5.7**	.52	.63	**.60**
11	Native, -	6	725	—	17.6	20.2	**19.4**	5.4	6.2	**5.8**	1.02	1.22	**1.13**
12	G. Jy., -	7	750	—	17.8	18.8	**18.3**	5.0	5.6	**5.3**	.92	1.03	**.97**
13	G. Jy., -	6	725	—	22.7	23.9	**23.3**	4.7	5.8	**5.5**	1.10	1.39	**1.28**
14	G. Hol., -	9	750	—	21.0	23.0	**21.9**	4.3	5.6	**4.7**	.92	1.17	**1.04**
	Herd avg., -	—	**750**	—	—	—	**17.4**	—	—	**5.5**	—	—	**.94**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (750 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value.	Per Average Weight (750 Lbs.) of Herd. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Grain,* - - -	13.6	3.00	.82	5.45	2.4	19200	10.2	2.25	.61	4.09	14400
Hay, 1st quality, -	5.4	.19	.06	2.55	—	—	4.0	.14	.04	1.91	—
Hay, 2d quality, -	5.4	.29	.04	2.20	—	—	4.0	.22	.03	1.65	—
Stover, - - -	8.8	.15	.05	3.56	—	—	6.7	.11	.04	2.67	—
Potatoes, - -	2.7	.03	-	.45	—	—	2.0	.02	–	.34	—
Total coarse food, -	22.3	.66	.15	8.76	13.8	18150	16.7	.49	.11	6.57	13550
Total food, -	**35.9**	**3.66**	**.97**	**14.21**	**4.5**	**37350**	**26.9**	**2.74**	**.72**	**10.66**	**27950**
Minimum per Day.											
Concentrated food,	12.7	2.80	.76	5.10	2.4	17900	9.5	2.10	.57	3.83	13400
Coarse food, - -	22.6	.65	.16	8.87	14.2	18400	17.0	.49	.12	6.65	13800
Total food, -	35.3	3.45	.92	13.97	4.7	36300	26.5	2.59	.69	10.48	27200
Maximum per Day.											
Concentrated food,	13.9	3.07	.84	5.57	2.4	19600	10.4	2.30	.63	4.18	14700
Coarse food, - -	22.8	.66	.15	8.98	14.1	18600	17.1	.50	.11	6.73	13900
Total food, -	36.7	3.73	.99	14.55	4.5	38200	27.5	2.80	.74	10.91	28600

* The grain used was mixed as follows: Wheat bran, 4.1 lbs.; linseed meal, 1 lb.; corn meal, 1 lb.; Buffalo gluten feed, 2 lbs; cotton seed meal, 2.1 lbs. Total, 10.2 lbs. per day per average weight of herd.

The following list of experiments during four successive winters will serve as a key to table 5 beyond, in which the rations of all the herds studied are briefly summarized:

Names and post-office addresses of owners of herds studied, dates at which they were visited, and reference number of herds.

No. of Herd.	Name and Post-Office Address of Owner.	Date of Test.
	Experiments of Winter of 1892–93.	
1,	W. S. Crane, Willimantic,	Nov. 30–Dec. 2.
2,	N. D. Potter, South Coventry,	Dec. 5–9.
3,	Samuel Stockwell, West Simsbury,	Dec. 12–17.
4,	C. P. Case, Simsbury,	Dec. 19–24.
5,	Edward Manchester, West Winsted,	Dec. 26–31.
6,	Isaac Barnes, Collinsville,	Jan. 2–7.
7,	Elbert Manchester, Bristol,	Jan. 9–14.
8,	Edward Norton, Farmington,	Jan. 16–21.
9,	H. W. Sadd, Wapping,	Jan. 23–28.
10,	John Thompson, Broad Brook,	Jan. 30–Feb. 4.
11,	E. F. Thompson, Warehouse Point,	Feb. 6–11.
12,	R. E. Holmes, West Winsted,	Feb. 13–18.
13,	James B. Blivin, Baltic,	Feb. 27–Mch. 4.
14,	George W. Woodbridge, Manchester Green,	Mch. 6–11.
15,	Harvey S. Ellis, Vernon Center,	Mch. 13–18.
16,	Charles P. Grosvenor, Abington,	Mch. 20–25.
	Experiments of Winter of 1893–94.	
18,	W. S. Crane, Willimantic,	Dec. 4–16.
19,	Harvey S. Ellis, Vernon Center,	Dec. 18–30.
20,	Clifton Peck, Lebanon,	Jan. 2–13.
21,	Same herd as No. 18,	Jan. 15–27.
22,	C. H. Lathrop, North Franklin,	Jan. 29–Feb. 10.
23,	Same herd as No. 20,	Feb. 12–24.
24,	W. F. Maine, South Windham,	Feb. 26-Mch. 3.
25,	Same herd as No. 22,	Mch. 5–17.
26,	Charles G. Nichols, West Willington,	Mch. 19–24.
	Experiments of Winter of 1894–95.	
27,	C. B. Davis, Yantic,	Dec. 10–22.
28,	W. F. Maine, South Windham,	Dec. 24–Jan. 5.
29,	Same herd as No. 27,	Jan. 7–19.
30,	Same herd as No. 28,	Jan. 21–Feb. 2.
31,	I. W. Trowbridge, Putnam,	Feb. 4–16.
32,	R. L. Sadd, Wapping,	Feb. 18–Mch. 2.
33,	Same herd as No. 31,	Mch. 4–16.
34,	Same herd as No. 32,	Mch. 18–30.
	Experiments of Winter of 1895–96.	
35,	Simon Brewster, Jewett City,	Dec. 3–14.
36,	H. R. Hayden, East Hartford,	Feb. 11–22.
37,*	Same as No. 35,	Dec. 22–Jan. 2.
38,	Same as No. 36,	Mch. 6–17.

* A test was begun on another herd January 7th, but during the second period had to be discontinued, and is not reported upon.

TABLE 5.

Summary of total and digestible nutrients fed per day per 1000 pounds, live weight, on dairy farms in Connecticut. Studies of four successive winters, 1892–93, 1893–94, 1894–95, and 1895–96.

Reference No.	Classes of Food.	Total Food.	Organic Matter.	Digestible Nutrients and Fuel Value.				
				Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.
1	Concentrated food,	8.3	7.2	1.58	.55	3.51	—	11790
	Coarse food,	43.6	18.3	.93	.44	9.73	—	21660
	Total food,	**51.9**	**25.5**	**2.51**	**.99**	**13.24**	**6.2**	**33450**
2	Concentrated food,	11.4	10.0	2.05	.49	5.58	—	16300
	Coarse food,	64.7	17.2	.74	.36	9 61	—	20700
	Total food,	**76.1**	**27.2**	**2.79**	**.85**	**15.19**	**6.1**	**37000**
3	Concentrated food,	10.7	9.4	2.39	.87	4.65	—	16770
	Coarse food,	27.9	17.5	.62	.28	10.13	—	21180
	Total food,	**38.6**	**26.9**	**3.01**	**1.15**	**14.78**	**5.7**	**37950**
4	Concentrated food,	10.6	9.2	1.47	.46	4.99	—	14000
	Coarse food,	30.5	22.0	1.15	.47	11.67	—	25800
	Total food,	**41.1**	**31.2**	**2.62**	**.93**	**16.66**	**7.0**	**39800**
5	Concentrated food,	8.2	7.2	2.20	.76	2.64	—	12200
	Coarse food,	46.3	22.4	.96	.49	12.55	—	27200
	Total food,	**54.5**	**29.6**	**3.16**	**1.25**	**15.19**	**5.7**	**39400**
6	Concentrated food,	7.5	6.5	1.23	.51	3.58	—	11100
	Coarse food,	26.6	20.1	.80	.36	10.97	—	23400
	Total food,	**34.1**	**26.6**	**2.03**	**.87**	**14.55**	**8.1**	**34500**
7	Concentrated food,	14.1	12.2	1.44	.65	7.70	—	19740
	Coarse food,	24.4	19.8	1.00	.44	10.30	—	22860
	Total food,	**38.5**	**32.0**	**2.44**	**1.09**	**18.00**	**8.4**	**42600**
8	Concentrated food,	12.2	10.4	1.60	.50	5.35	—	15050
	Coarse food,	28.7	23.3	1.56	.43	11.60	—	26300
	Total food,	**40.9**	**33.7**	**3.16**	**.93**	**16.95**	**6.0**	**41350**
9	Concentrated food,	7.4	6.3	1.20	.58	3.14	—	10500
	Coarse food,	22.2	16.5	.96	.25	8.91	—	19450
	Total food,	**29.6**	**22.8**	**2.16**	**.83**	**12.05**	**6.4**	**29950**

TABLE 5.—*(Continued.)*

Reference No.	Classes of Food.	Total Food.	Organic Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.
10	Concentrated food, -	8.2	7.0	1.09	.50	3.72	—	11100
	Coarse food, - -	22.3	17.4	1.23	.34	9.32	—	21000
	Total food, - -	**30.5**	**24.4**	**2.32**	**.84**	**13.04**	**6.4**	**32100**
11	Concentrated food, -	10.2	8.9	1.91	.70	4.17	—	14250
	Coarse food, - -	22.6	17.5	.85	.31	9.29	—	20200
	Total food, - -	**32.8**	**26.4**	**2.76**	**1.01**	**13.46**	**5.7**	**34450**
12	Concentrated food, -	13.1	11.1	2.29	.56	4.84	—	15650
	Coarse food, - -	48.5	12.3	.70	.38	6.57	—	15100
	Total food, - -	**61.6**	**23.4**	**2.99**	**.94**	**11.41**	**4.5**	**30750**
13	Concentrated food, -	11.2	9.7	1.67	.64	5.27	—	15600
	Coarse food, - -	38.2	10.8	.53	.28	5.90	—	13150
	Total food, - -	**49.4**	**20.5**	**2.20**	**.92**	**11.17**	**6.0**	**28750**
14	Concentrated food, -	9.4	8.4	1.71	.64	3.79	—	12900
	Coarse food, - -	22.3	17.8	.95	.41	9.30	—	20850
	Total food, - -	**31.7**	**26.2**	**2.66**	**1.05**	**13.09**	**5.8**	**33750**
15	Concentrated food, -	8.8	7.5	.70	.37	4.79	—	11800
	Coarse food, - -	20.3	16.3	.65	.19	9.20	—	19100
	Total food, - -	**29.1**	**23.8**	**1.35**	**.56**	**13.99**	**11.3**	**30900**
16	Concentrated food, -	6.9	6.0	.61	.46	3.74	—	10100
	Coarse food, - -	21.7	16.8	.83	.34	8.92	—	19500
	Total food, - -	**28.6**	**22.8**	**1.44**	**.80**	**12.66**	**9.3**	**29600**
18	Concentrated food, -	12.3	10.6	1.80	.55	5.61	3.9	16100
	Coarse food, - -	32.2	20.0	.80	.45	10.84	15.0	23600
	Total food, - -	**44.5**	**30.6**	**2.60**	**1.00**	**16.45**	**7.3**	**39700**
19	Concentrated food, -	10.7	9.2	2.00	.68	4.65	3.2	15200
	Coarse food, - -	18.9	15.3	.70	.25	8.48	13.0	18100
	Total food, - -	**29.6**	**24.5**	**2.70**	**.93**	**13.13**	**5.7**	**33300**
20	Concentrated food, -	12.1	10.6	1.22	.39	6.42	6.1	15800
	Coarse food, - -	24.5	17.6	.75	.25	8.67	12.4	18600
	Total food, - -	**36.6**	**28.2**	**1.97**	**.64**	**15.09**	**8.5**	**34400**

TABLE 5.—*(Continued.)*

Reference No.	Classes of Food.	Total Food.	Organic Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.
* 21	Concentrated food, -	12.5	10.8	2.19	.59	5.15	3.0	16100
	Coarse food, - -	29.9	16.4	.71	.40	8.88	13.9	19500
	Total food, - -	**42.4**	**27.2**	**2.90**	**.99**	**14.03**	**5.7**	**35600**
22	Concentrated food, -	10.0	8.6	1.06	.29	5.05	5.4	12600
	Coarse food, - -	16.4	14.3	.85	.27	7.46	9.6	16600
	Total food, - -	**26.4**	**22.9**	**1.91**	**.56**	**12.51**	**7.3**	**29200**
* 23	Concentrated food, -	11.8	10.3	1.96	.42	5.38	3.3	15400
	Coarse food, - -	22.8	16.5	.72	.24	8.17	12.2	17550
	Total food, - -	**34.6**	**26.8**	**2.68**	**.66**	**13.55**	**5.7**	**32950**
24	Concentrated food, -	13.6	11.5	1.97	.51	6.54	4.0	18000
	Coarse food, - -	20.4	16.8	1.51	.31	8.28	6.0	19500
	Total food, - -	**34.0**	**28.3**	**3.48**	**.82**	**14.82**	**4.8**	**37500**
* 25	Concentrated food, -	10.8	9.3	1.60	.40	5.06	3.8	14100
	Coarse food, - -	16.8	14.7	.88	.31	7.48	9.4	16800
	Total food, - -	**27.6**	**24.0**	**2.48**	**.71**	**12.54**	**5.8**	**30900**
26	Concentrated food, -	10.6	8.6	1.95	.83	4.16	3.2	14900
	Coarse food, - -	14.3	12.0	.57	.22	6.31	12.1	13700
	Total food, - -	**24.9**	**20.6**	**2.52**	**1.05**	**10.47**	**5.2**	**28600**
27	Concentrated food, -	15.2	13.2	1.65	.58	8.15	5.7	20700
	Coarse food, - -	21.2	12.9	.50	.18	7.51	15.8	15650
	Total food, - -	**36.4**	**26.1**	**2.15**	**.76**	**15.66**	**8.0**	**36350**
28	Concentrated food, -	14.5	12.9	1.41	.49	8.12	6.5	19750
	Coarse food, - -	20.3	17.8	.77	.32	10.13	14.1	21100
	Total food, - -	**34.8**	**30.7**	**2.18**	**.81**	**18.25**	**9.2**	**40850**
* 29	Concentrated food, -	20.7	17.9	2.97	.69	9.20	3.6	25550
	Coarse food, - -	16.2	13.8	.51	.17	8.08	16.6	16700
	Total food, - -	**36.9**	**31.7**	**3.48**	**.86**	**17.28**	**5.5**	**42250**
* 30	Concentrated food, -	11.9	10.1	1.67	.35	5.68	3.9	15150
	Coarse food, - -	17.8	14.9	.74	.24	8.43	12.1	18100
	Total food, - -	**29.7**	**25.0**	**2.41**	**.59**	**14.11**	**6.4**	**33250**

* Rations suggested by the Station, see page 74.

TABLE 5.—*(Continued.)*

Reference No.	Classes of Food.	Total Food.	Organic Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.
31	Concentrated food, -	8.2	7.1	.90	.29	3.93	5.1	10250
	Coarse food, - -	55.2	16.9	.75	.53	9.64	14.4	21550
	Total food, - -	**63.4**	**24.0**	**1.65**	**.82**	**13.57**	**9.3**	**31800**
32	Concentrated food, -	10.4	9.3	2.18	1.08	4.18	3.0	16400
	Coarse food, - -	18.3	15.0	.58	.28	8.51	15.8	18100
	Total food, - -	**28.7**	**24.3**	**2.76**	**1.36**	**12.69**	**5.7**	**34500**
* 33	Concentrated food, -	11.0	9.5	1.43	.55	4.99	4.4	14250
	Coarse food, - -	19.6	16.3	1.36	.39	8.14	6.6	19300
	Total food, - -	**30.6**	**25.8**	**2.79**	**.94**	**13.13**	**5.5**	**33550**
* 34	Concentrated food, -	10.2	9.0	2.05	.82	3.94	2.8	14600
	Coarse food, - -	20.4	15.9	.74	.29	8.95	13.0	19250
	Total food, - -	**30.6**	**24.9**	**2.79**	**1.11**	**12.89**	**5.5**	**33850**
35	Concentrated food, -	9.4	8.1	1.01	.38	5.14	5.9	13050
	Coarse food, - -	22.8	19.0	.83	.34	9.85	12.8	21300
	Total food, - -	**32.2**	**27.1**	**1.84**	**.72**	**14.99**	**9.0**	**34350**
36	Concentrated food, -	12.6	11.1	2.36	.54	5.84	3.0	17500
	Coarse food, - -	25.4	18.6	.77	.18	10.10	13.7	21000
	Total food, - -	**38.0**	**29.7**	**3.13**	**.72**	**15.94**	**5.6**	**38500**
* 37	Concentrated food, -	8.8	7.8	1.79	.43	4.06	2.8	12700
	Coarse food, - -	20.2	17.0	1.14	.21	8.96	8.2	19700
	Total food, - -	**29.0**	**24.8**	**2.93**	**.64**	**13.02**	**4.9**	**32400**
* 38	Concentrated food, -	13.6	11.9	3.00	.82	5.45	2.4	19200
	Coarse food, - -	22.3	16.0	.66	.15	8.76	13.8	18150
	Total food, - -	**35.9**	**27.9**	**3.66**	**.97**	**14.21**	**4.5**	**37350**
	Average of the above 38 Rations.							
	Concentrated food, -	10.8	9.3	1.67	.55	4.95	3.7	14650
	Coarse food, - -	25.9	16.4	.82	.31	8.83	11.6	19250
	Total food, - -	**36.7**	**25.7**	**2.49**	**.86**	**13.78**	**6.3**	**33900**
	*Average of 29 of the above Rations.**							
	Concentrated food, -	10.3	8.9	1.54	.55	4.80	3.9	14100
	Coarse food, - -	27.6	16.6	.82	.32	8.96	11.8	19550
	Total food, - -	**37.9**	**25.5**	**2.36**	**.87**	**13.76**	**6.7**	**33650**

* Nine of the above rations (Nos. 21, 23, 25, 29, 30, 33, 34, 37, and 38) were suggested by the Station, as explained on page 53. Hence the twenty-nine other rations, the average of which is here given, actually represent the feeding practice of these dairymen.

Table 5 on pages 65 to 68, gives a summary of 38 rations used in feeding the dairy herds studied by the Station. Nine of these rations were, however, suggested by the Station, and therefore only 29 of them actually represent the feeding practice of these dairymen.

The total weights of food fed per 1,000 pounds live weight are given in the first column of figures. As explained above, all of the foods used in these experiments were carefully analyzed and their chemical composition is therefore known. The weights of digestible nutrients were obtained by the use of factors (digestion coefficients), as explained on page 58. The last column but one contains the nutritive ratio, and the last column gives the calculated fuel value of the digestible nutrients in the rations.

It is possible to compare different rations by the quantities of digestible protein or flesh formers which they contain and the fuel value of their digestible nutrients. The extremes of these rations are pointed out in the following table, by comparing the maximum and minimum of organic matter, protein, fat, carbohydrates, fuel value, and nutritive ratio of all the rations in each case:

	Organic Matter.	Digestible Protein.	Digestible Fat.	Digestible Carbohydrates.	Fuel Value of Digestible Nutrients.	Nutritive Ratio.
	Lbs.	Lbs.	Lbs.	Lbs.	Calories.	1:
Minimum, 27 rations,	20.5	1.35	.56	10.47	28600	4.5
Maximum, 27 rations,	33.7	3.48	1.36	18.25	42600	11.3
Average, 27 rations,	25.5	2.36	.87	13.76	33650	6.7

RATIONS FOR MILCH COWS.

A proper ration for an animal must supply the materials needed for the maintenance of its body and for the production demanded from it.

The amounts and proportions of these nutrients needed for the physiological demands will vary with the animal and with the kind and amount of production. For maintenance the body needs certain amounts of material, chiefly protein, to build its tissues and keep them in repair, and certain amounts of other materials, chiefly carbohydrates and fats, to serve as fuel for supplying the energy which the body needs for heat and work. For growth, the proportion of protein must be liberal. For

6

fattening, there must also be a liberal amount of protein if the increase of "flesh," so-called, is to include any considerable amount of lean, though in many cases, and especially with some breeds of swine, a large amount of fat can be stored in the body from fats and even from carbohydrates in the food. For muscular work, the ratio of protein to fuel ingredients may vary with the amount and intensity of the work, but it appears from the results of the latest and most reliable experimenting that for the intenser forms of muscular work considerable protein is necessary, although the fats and carbohydrates are the chief sources of fuel for the animal machine, and more of them is needed in proportion as more of the muscular work is done.

For the production of milk, the need of a liberal proportion of protein in the food is becoming more and more apparent as accurate experiments and observations accumulate. Just why so much protein is necessary, physiology is not yet able to explain clearly and in detail. But it is not easy to see how any one can look through the evidence which has accumulated, during the last twenty years, without being impressed by the importance which the protein of food plays in milk production. In the Reports and Bulletins of this Station the need of protein in the feed of milch cows has been constantly insisted upon. In the previous accounts of the experiments of the series here discussed this principle has been brought out very clearly. In general the best milk production has been found where the most protein has been fed, and in several instances where the farmers have been feeding rather wide rations and afterwards changed to narrower rations by increasing the protein, an improvement in the milk production was manifest. Naturally there have been some apparent exceptions, as is always to be expected where the periods of observation are so short as this. But as a rule liberal rations with abundant protein and narrow nutritive ratios and large amounts of milk, and milk rich in fat as well as protein, have gone together. So true is this that we feel justified in speaking even more emphatically than we did at the outset of the value of nitrogenous feeding stuffs in the dairy.

Just what weights of different food constituents are best for a given herd or for a given cow on a given farm cannot be told with certainty. As we have frequently insisted, it is impossible to lay down hard and fast rules for feeding.

Still it is possible to set up certain feeding standards which may be followed with more or less actual advantage to the feeder.

TABLE 6.

Rations as fed by dairymen, and proposed standards. Digestible nutrients, per 1000 pounds live weight, daily.

RATION.	Organic Matter.	Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.
	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Rations as fed by Dairymen:						
Average of 128 American rations,*	24.5	2.15	.74	13.27	31250	6.9
Average of 29 rations as fed in Connecticut, 1892–96, - -	25.5	2.36	.87	13.76	33650	6.7
Average of 9 rations suggested by Storrs Station and fed in Connecticut, 1892–96, - -	26.4	2.90	.83	13.86	34700	5.4
Standard rations:						
Ration as tentatively suggested by Storrs Station, - -	25.0	2.5	(.5 to .8)	(13 to 12)	31000	5.6
Wolff's (German) standard, -	24.0	2.5	.4	12.5	29600	5.4
Lehmann's (German) standards for cows with different milk yields—Milk per cow per day:						
5 kilos or 11 pounds, -	25.0	1.6	.3	10.0	22850	6.7
7½ kilos or 16½ pounds, -	27.0	2.0	.4	11.0	25850	6.0
10 kilos or 22 pounds, -	29.0	2.5	.5	13.0	30950	5.7
12½ kilos or 27½ pounds, -	32.0	3.3	.8	13.0	33700	4.5

The table above gives a number of results of observations as to the rations actually fed by dairymen, and with them several feeding standards for milch cows. They are intended to show the amounts of nutrients in the food per day and per thousand pounds of live weight of the animal. In each case the quantities represent the digestible nutrients and the fuel value of the daily ration.

The first represents the average of 128 rations compiled by the Wisconsin Experiment Station.* The figures for the amounts of foods in these rations were obtained in response to letters sent to "dairy farmers and breeders of dairy stock in all parts of the United States and Canada, asking information concerning their methods of feeding milch cows." The quantities of food as given by the individual feeders were based

* Wisconsin Experiment Station, Bulletin 38.

generally upon their estimates rather than upon actual weighings of the amounts fed each day to the cows. The quantities of digestible nutrients were calculated from average analyses and from assumed figures for digestibility of each class of nutrients. The average of these rations indicates the use of less protein and more fuel ingredients of food by these intelligent farmers and breeders than the commonly quoted feeding standards call for. This, however, is not at all unnatural.

The relative abundance and cheapness of feeding stuffs containing the fats, and especially carbohydrates, has doubtless led to their very extensive use in this country, but the fact that intelligent men feed them liberally does not imply, and much less does it prove, that we are using them wisely.

The second average in the table is that of twenty-nine studies of the feeding practice of Connecticut dairymen, here reported. It will be observed that they are, on the whole, more liberal and, especially, that they contain considerably larger proportions of protein than the average of the larger number of rations compiled by the Wisconsin Station.

The next ration represents the average of nine which were suggested by the Station to farmers as the result of observations upon their actual feeding practice. In each of these cases, a study was first made of the materials fed and the milk produced. A change in the ration was then suggested by the Station and adopted by the owner of the herd. This change consisted partly in using more nitrogenous feeding stuffs and partly in replacing the finer and more valuable kinds of hay by coarser and cheaper fodder, as explained in detail in the accounts of the experiments. In general the new rations with the larger amounts of protein and narrower nutritive ratios were found decidedly advantageous, as will be explained beyond.

The next is a feeding standard tentatively suggested by the Station. This, it will be observed, contains the same amount of protein as is called for in the German standard by Wolff, which follows next in the table. The amounts of fuel ingredients are, however, a little larger, so that the fuel value is 31,000 calories as compared with 29,600 in the German standard ration. While the German figures probably come nearer to the physiological demand for the average milch cow, especially if the amount of milk is to be at all considered, this more liberal

supply of carbohydrates and wider nutritive ratio was suggested in view of the important practical fact that carbohydrates and fats are relatively cheap and protein dear in Connecticut.

The next is the standard proposed by the German physiological chemist and experimenter, Wolff. It is one of the standards of which a considerable number, for animals of different kinds, were proposed by this eminent authority a number of years ago and have been quoted very extensively by writers upon the subject in Europe and in this country during the past twenty years. Like the other standards proposed by Wolff, Kühn, Lehmann, and others in Germany, and by other investigators and writers elsewhere, it is meant simply as a general indication of the amounts and proportions of nutrients fitted for the average animal of the kind, and under average conditions. It was understood and constantly insisted upon by these writers that the best proportions in a given case would vary with the conditions of that particular case,* and that the proper thing for the farmer to do is to study carefully what feeding stuffs he has and can buy, how much they will cost, how his cows actually respond to different kinds and amounts of fodder, and simply make these feeding standards one of the factors of his estimate of what will be best for him to feed.

The remaining German standards in the table are by Dr. Lehmann, a German authority on these subjects. They are published in the well-known German farmers' almanac, *Mentzel und v. Lengerke's landwirtschaftlicher Kalender*, for 1897, and indicate the drift of opinion in Germany where these subjects are studied more thoroughly than anywhere else in the world.

It may be said by way of explanation that for many years this farmers' almanac has contained, with other things, Wolff's tables of the composition and digestibility of feeding stuffs and feeding standards. These almanacs (or pocket diaries) are in constant use by tens of thousands of the German farmers and feeders, and the statistics which they contain, including those for feeding, are intended to represent what will be, practically, most useful to the feeder. To this end Prof. Wolff has, for more than a quarter of a century past, continually altered them in accordance with the teachings of experience and experimenting. Prof. Wolff has lately died and Dr. Lehmann in continuing

* See discussion of this subject in the Report of this Station for 1894, pp. 205-216.

his work has made some changes in the feeding standards to fit them to the later experience of experimenters and feeders. In the standard for milch cows, particularly, he has attempted to give numerical expression to a fact which has forced itself more and more into view, that the ration should be fitted to the amount of milk given by the cows. In thus attempting to calculate rations for different daily milk yields, Dr. Lehmann has increased the protein more than the fuel ingredients, that is to say, he has made the ration narrower in proportion as the milk yield is larger. This is in accordance with the principle above referred to, that a cow needs a liberal amount of protein to produce a large amount of milk.

Really, there are two principles which underlie this view of the subject. One is that with the improvement of breeds during the last twenty-five years or more there has been a great increase in the amount of milk produced by cows. The standard for milk production of a cow, if we may use the expression, has during this time been constantly rising. Supposing the need for maintenance of the cow's body to remain the same, the extra material needed for milk production has been, consequently, increasing, and hence a larger ration ought to be assigned for a high-bred milk-producing cow to-day than for the cow of twenty-five years ago. The other is that the food for the production of milk over and above that for maintenance needs to be rich in protein. On these two principles rests the theory expressed in the large rations with large amounts of protein and narrow nutritive ratios for large milk production by cows.

Just as it is useless to lay down hard and fast rules for feeding, or exact figures for standard rations, so it is impossible to make categorical statements which shall be true in every particular. What has just been said, therefore, about liberal rations, and about large amounts of protein and narrow nutritive ratios for milch cows, is to be taken just as it is meant, namely, as a general statement of a general principle and nothing more.

THE EXPERIMENTS OF THE WINTER OF 1895–96.

The cost of the feeding stuffs, the pecuniary results of the experiments, the rations fed, and the physiological effects resulting from their use are briefly discussed in the following pages.

The figures used for estimating the values of the feeding stuffs, *i. e.*, the market prices per ton and the values of manure obtainable from one ton of each of the feeding stuffs are stated in the accompanying table:

Valuation of feeding stuffs as used in rations fed milch cows in winter of 1895–96.

Feeding Stuffs.	Market Price per Ton of Feeding Stuffs.	Estimated Value of the Manure Obtainable from One Ton of Feeding Stuffs.
Wheat bran, - - - - - -	$13.00	$12.00
Wheat middlings, No. 1, - - -	14.00	10.00
Cotton seed meal, - - - - -	23.00	23.00
Buffalo gluten feed, - - - -	14.00	12.00
Chicago gluten meal, - - - -	18.00	15.00
O. P. linseed meal, - - - -	22.00	19.00
Corn meal, - - - - - -	14.00	7.00
Hay, 1st quality, - - - - -	16.00	6.00
Hay, 2d quality, - - - - -	12.00	6.00
Oat hay, - - - - - -	12.00	6.00
Corn stover, - - - - - -	8.00	5.00
Clover hay, - - - - - -	14.00	9.00
Potatoes, small, - - - - -	10c. per bu.	—

The prices of the feeding stuffs used in calculating the cost of rations were those current in November, 1896. They were obtained, in the case of the grain feeds, by sending circulars to grain dealers in five Connecticut cities asking the current prices of grains in ton lots, and averaging the figures thus obtained. The coarse fodders are based upon the market value of the various materials as estimated by farmers. The manurial value is based upon figures given in the Report of the Massachusetts Agricultural Experiment Station for 1893, pp. 358–365. The nitrogen in the feeding stuff is counted as worth 17½ cents, the phosphoric acid at 5 cents, and the potash at 5½ cents per pound for manure, and it is assumed that 85 per cent. of the quantities in the food may be saved in the manure. Unfortunately, most farmers take such poor care of the manure produced from the materials fed to their stock, that a much smaller percentage is usually saved.

DAIRY HERD H.—TESTS 35 AND 37.

The dairy herd represented in these tests was studied December 3–14, 1895. After an interval of nine days, during which the Station representative made the change of feed, the same

herd was again studied December 22, 1895–January 2, 1896. There were eleven animals in each test, the cows being the same in both. Five of the animals were grade Jerseys, and the rest were natives. The average estimated weight was 775 pounds, and the average age nine years. At the date of the first test the average time since last calf was four months. The rations fed are shown in the table herewith. The main change made in the second ration was the substitution of clover hay and Chicago gluten meal for the oat hay and corn meal fed in the first ration. This narrowed the nutritive ratio from 1:9 to about 1:5, and, of course, increased the proportion of protein.

Dairy Herd H.—Tests 35 and 37.—Calculated per head of 775 pounds, live weight.

Feeding Stuffs. Kind.	Amount.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Cost.	Value of Obtainable Manure.	Net Cost.
First Test. Dec. 3 to Dec. 14, 1895. 12 Days.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
Grain, etc., Corn meal,	3.2								
Wheat bran,	1.7	.78	.29	3.98	10050	5.9	6.5	4.2	2.3
Wheat middlings,	2.4								
Hays, etc., Oat hay,	6.8	.64	.27	7.63	16550	12.8	10.8	6.1	4.7
Corn stover,	10.9								
Total food,	**25.0**	**1.42**	**.56**	**11.61**	**26600**	**9.0**	**17.3**	**10.3**	**7.0**
Second Test. Dec. 22,'95, to Jan. 2,'96. 12 Days.									
Grain, etc., Gluten meal,	3.1								
Wheat bran,	1.5	1.39	.33	3.15	9850	2.8	6.9	5.6	1.3
Wheat middlings,	2.2								
Hays, etc., Clover hay,	6.4	.88	.16	6.94	15200	8.2	10.5	6.7	3.8
Corn stover,	9.2								
Total food,	**22.4**	**2.27**	**.49**	**10.09**	**25050**	**4.9**	**17.4**	**12.3**	**5.1**

The total cost of the ration remained practically the same, but the net cost was greatly reduced in the second test, owing to the higher value of the manure. The average daily yield of milk was increased during the second test seven-tenths of a pound and the butter five-hundredths of a pound over that obtained in the first test. The total cost of feed to produce 100 pounds of milk was reduced four cents, and the cost of feed for a pound of butter was reduced two cents, in the second test.

DAIRY HERD I.—TESTS 36 AND 38.

This herd was studied February 11–22, and again March 6–17, 1896. There were fourteen animals in each test, the cows being the same in both. They consisted of nine grade Jerseys, two grade Holsteins, and three natives. The average weight of the herd was estimated at 750 pounds, and the average age six years. The ration fed in the first test was an exceptionally heavy one, and the nutritive ratio was very nearly that of the standard suggested by the Station. In order to study the effect of large quantities of protein, and a narrower nutritive ratio, the quantity of protein was increased from 2.34 pounds to 2.74 pounds per day per cow. In the second test the average quantity of milk was increased four-tenths of a pound, and the quantity of butter seven-hundredths of a pound per day. By reference to the tables on pages 61 and 63 it will be seen that the fat was increased in the second test from two to five-tenths of a per cent. in the case of nearly every cow.

Dairy Herd I.—Tests 36 and 38.—Calculated per head of 750 pounds, live weight.

Feeding Stuffs.			Digestible Nutrients and Fuel Value.							
Kind.		Amount.	Protein.	Fat.	Carbohydrates.	Fuel Value.	Nutritive Ratio.	Cost.	Value of Obtainable Manure.	Net Cost.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
First Test. *Feb. 11 to Feb. 22, 1896. 12 Days.*										
Grain, etc.,	Wheat bran,	3.7	1.77	.40	4.38	13150	3.0	9.5	7.7	1.8
	Linseed meal,	1.6								
	Corn meal,	1.6								
	Buff. gluten meal,	2.5								
Hays, etc.,	Hay, 1st quality,	5.0	.57	.13	7.58	15700	13.7	13.5	6.4	7.1
	Hay, 2d quality,	5.0								
	Stover,	7.1								
	Potatoes,	2.0								
Total food,		28.5	2.34	.53	11.96	28850	5.6	23.0	14.1	8.9
Second Test. *Mar. 6 to Mar. 17, 1896. 12 Days.*										
Grain, etc.,	Wheat bran,	4.1	2.25	.61	4.09	14400	2.4	10.3	8.7	1.6
	Linseed meal,	1.0								
	Corn meal,	1.0								
	Buff. gluten meal,	2.0								
	Cotton seed meal,	2.1								
Hays, etc.,	Hay, 1st quality,	4.0	.49	.11	6.57	13550	13.8	11.4	5.4	6.0
	Hay, 2d quality,	4.0								
	Stover,	6.7								
	Potatoes,	2.0								
Total food,		26.9	2.74	.72	10.66	27950	4.5	21.7	14.1	7.6

The total cost of each of the rations was large, although the second ration was slightly less expensive than the first. Quite a number of cows in the herd were well along in the period of lactation, and were no doubt being fed too heavily for the amount of product they were giving. It is very interesting to note that the experiment seems to corroborate results obtained at the Massachusetts and Pennsylvania Experiment Stations* in showing that heavy protein rations, if any, are the ones that tend to increase the percentage of fat in the milk.

COMPARISON OF TESTS WITH WIDER AND NARROWER RATIONS.

The experiments of the last three seasons—1893–94, 1894–95 and 1895–96—include nine cases in which comparative tests were made by feeding two different rations in succession to the same herd, in the manner described above, pages 53 and 54. In each case the ration actually being fed in the ordinary method practiced on the farm was determined by weighing the feeding stuffs on the spot as they were fed and taking samples for analyses, and at the same time weighing the milk of each cow and determining the percentage of butter-fat. As soon as the analyses of the feeding stuffs could be made, so as to calculate the amounts of nutrients, another ration was made up which was assumed to be a nearer approach to the accepted standards and a second test was made with this ration, the fodder and milk being weighed and analyzed as before. In eight of the cases the second ration was narrower than the first; in one instance the first ration was comparatively narrow, and the change was mainly from more to less expensive food materials. The length of each test was twelve days. The interval between the two tests of each comparative trial was from two to four weeks in the seven comparative experiments of 1893–94 and 1894–95, and nine days in the two of 1895–96.

The results of the eighteen tests with nine herds are summarized in the following table. The rations fed each herd in the different tests, the cost of the rations, the daily milk and butter product, and the cost of food to produce 100 pounds of milk and one pound of butter, are given in such a way that the results from the two rations can be easily compared.

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* Massachusetts State Station Report, 1894, p. 43; Pennsylvania Experiment Station Report, 1895, p. 71.

Summary of daily rations fed, and daily milk and butter yield from nine herds with a wide as compared with a narrower ration.

Herd.	Average Weight of Cows.	No. of Test.	Daily Ration per Head.					Average Daily		Cost of Food to Produce			
										100 lbs. Milk.		1 lb. Butter.	
			Digestible Protein.	Fuel Val. of Digestible Nutrients.	Nutritive Ratio.	Total Cost.	Net Cost.*	Milk Flow.	Yield of Butter.†	Total Cost.	Net Cost.*	Total Cost.	Net Cost.*
	Lbs.		Lbs.	Cal.	1:	Cts.	Cts.	Lbs.	Lbs.	$	Ct	Ct	Ct
A { Wide ration,	825	18	2.15	32750	7.3	26.6	14.3	18.1	1.10	1.47	79	24	13
A { Nar. ration,	825	21	2.39	29400	5.7	21.7	9.8	18.9	1.12	1.15	52	19	9
B { Wide ration,	750	20	1.49	25800	8.5	18.6	9.5	18.1	.90	1.00	53	21	11
B { Nar. ration,	750	23	2.01	24700	5.7	18.3	9.0	17.9	.92	1.03	50	20	10
C { Wide ration,	725	22	1.38	21150	7.3	19.4	12.5	13.7	.67	1.41	91	29	19
C { Nar. ration,	725	25	1.80	22400	5.7	17.8	9.9	13.6	.71	1.30	73	25	14
D { Wide ration,	600	27	1.29	21800	8.0	14.1	7.0	14.0	.79	1.01	50	18	9
D { Nar. ration,	600	29	2.09	25350	5.5	15.1	6.9	13.7	.76	1.10	50	20	9
E { Wide ration,	750	28	1.63	30650	9.2	18.4	10.5	17.9	1.02	1.03	59	18	10
E { Nar. ration,	750	30	1.81	24950	6.4	15.9	7.1	18.3	1.07	.87	39	15	7
F { Wide ration,	800	31	1.32	25450	9.3	15.1	6.8	17.8	1.01	.85	38	15	7
F { Nar. ration,	800	33	2.23	26850	5.5	18.0	7.0	18.5	1.04	.97	38	17	7
G { 1st ration,	775	32	2.14	26750	5.7	16.7	7.6	17.7	.98	.94	43	17	8
G { 2d ration,	775	34	2.16	26200	5.5	16.2	5.6	15.4	.90	1.05	36	18	6
H { Wide ration,	775	35	1.42	26600	9.0	17.3	7.0	16.7	.84	1.04	42	21	8
H { Nar. ration,	775	37	2.27	25050	4.9	17.4	5.1	17.4	.90	1.00	29	19	6
I { 1st ration,	750	36	2.34	28850	5.6	23.0	8.9	17.0	1.02	1.35	52	23	9
I { 2d ration,	750	38	2.74	27950	4.5	21.7	7.6	17.4	1.10	1.25	44	20	7
Average 9 tests with wide rations, - -	750	–	1.68	26650	7.5	18.6	9.4	16.8	.93	1.12	56	21	10
Average 9 tests with narrower rations, - -	750	--	2.17	25900	5.6	18.0	7.6	16.8	.95	1.08	46	19	8
Standard suggested by the Station,‡ -	—	–	2.50	31000	5.6	—	—	—	—	—	-	-	-

* Total cost less value of obtainable manure.

† Assuming butter to contain 82.4 per cent. butter-fat and 96.3 per cent. of the fat in the whole milk to be saved in the butter.

‡ This is nominally for 1000 pounds live weight, but, actually, a smaller cow in full flow of milk needs more than a large cow giving less milk. It may, therefore, apply to cows no larger than some of those in the above tests.

THE EFFECT OF NARROW RATIONS ON MILK FLOW AND BUTTER YIELD.

At the time of the second test the cows were, in each case, one to four weeks further along in the period of lactation, and would, in consequence, naturally have fallen off in milk flow

and butter yield. It is impossible to say exactly how much this natural shrinkage in milk would have been. In animals as near calving as some of these were the shrinkage would have been large; while in the case of cows in "flush," the decrease would have been less marked. The shrinkage in butter yield would, of course, be less, because the milk grows richer in fat as the period of lactation advances.

From the summary of the past three winters' work it will be seen that there was an increase in milk flow in five cases (herds A, E, F, H, and I,) when the animals were fed a narrow ration, over that obtained with the wider ration, and in two other cases (herds B and C) the yields were essentially the same in both tests, although in those instances the narrow ration was fed four weeks after the wide. Of the eight herds which were fed the wide ration, followed by a narrower one, all except one (D) gave an increase in butter yield during the second test. The fact that there was more often an increase in butter yield (calculated from the butter-fat) than in the milk yield, during the period when the narrow rations were fed, would indicate an increase in the percentage of fat as a result of using the narrow rations. In some instances this was noticeably the case. In herd C, with no increase in milk flow, there is quite a little gain in butter, while in herd I the contrast is still more noticeable. No determinations were made of the percentages of the other constituents of the milk.

Although a shrinkage in production would naturally follow from advancement in period of lactation, the herds as a whole more than held their own when changed to the narrower ration from one to four weeks after the first test. The results are in accord with observation and experiment elsewhere in that so far as physiological effects are concerned narrow (nitrogenous) rations give larger yields of both milk and butter than do wide (carbonaceous) rations.

COSTS OF THE DIFFERENT RATIONS.

Omitting herd G and considering only the eight herds which were fed a narrower ration following a wider one, there are six cases where the total cost of producing 100 pounds of milk is less with the narrower ration, and six cases where the cost of one pound of butter is less. One or more nitrogenous grain

feeds, like cotton seed, gluten or linseed meals, were usually substituted in the second test for a part of the corn and wheat feeds used in the first test. The total cost of the rations and the net cost, after deducting the estimated manurial value, is shown in the summary table. In getting the net cost, the manurial value is estimated by assuming that 85 per cent. of the nitrogen, phosphoric acid and potash of the feeding stuffs are obtainable in the manure, and that they have the same value as in ordinary commercial fertilizers. The following tables give the costs of food to produce 100 pounds of milk and one pound of butter.

Cost of food to produce 100 pounds of milk.

Herd.	Year.	Total Cost of Feed.		Net Cost of Feed.*	
		Wide Ration.	Narrower Ration.	Wide Ration.	Narrower Ration.
		Dollars.	*Dollars.*	*Dollars.*	*Dollars.*
A, - - - - - -	1893-4	1.47	1.15	.79	.52
B, - - - - - -	1893-4	1.00	1.03	.53	.50
C, - - - - - -	1893-4	1.41	1.30	.91	.73
D, - - - - - -	1894-5	1.01	1.10	.50	.50
E, - - - - - -	1894-5	1.03	.87	.59	.39
F, - - - - - -	1894-5	.85	.97	.38	.38
G, - - - - - -	1894-5	1.05	.94	.43	.36
H, - - - - - -	1895-6	1.04	1.00	.42	.29
I, - - - - - -	1895-6	1.35	1.25	.52	.44
Average, - - - - -	—	1.13	1.07	.56	.46

* Total cost less that of obtainable manure.

Cost of food to produce one pound of butter.

Herd.	Year.	Total Cost of Feed.		Net Cost of Feed.*	
		Wide Ration.	Narrower Ration.	Wide Ration.	Narrower Ration.
		Dollars.	*Dollars.*	*Dollars.*	*Dollars.*
A, - - - - - -	1893-4	.24	.19	.13	.09
B, - - - - - -	1893-4	.21	.20	.11	.10
C, - - - - - -	1893-4	.29	.25	.19	.14
D, - - - - - -	1894-5	.18	.20	.09	.09
E, - - - - - -	1894-5	.18	.15	.10	.07
F, - - - - - -	1894-5	.15	.17	.07	.07
G, - - - - - -	1894-5	.18	.18	.08	.06
H, - - - - - -	1895-6	.21	.19	.08	.06
I, - - - - - -	1895-6	.23	.20	.09	.07
Average, - - - - -	—	.21	.19	.10	.08

* Total cost less that of obtainable manure.

SUMMARY.—THE EXPERIMENTS AND RESULTS.

In the winter of 1892–93, the Station began making systematic observations of the winter feeding practices of Connecticut dairymen. The chief points upon which information was obtained were: Number of animals in the herd; breed, age, and approximate weight of each cow; length of time since dropping last calf and till due to calve again; kinds, weights, and chemical composition of feeding stuffs used; weights of milk flow; percentages and amounts of butter-fat in the milk.

The feeding stuffs used on these farms included quite a long list, but those that tend to make a wide ration were employed in much greater proportions than were those which tend to make rations narrow. The following is a nearly complete list. The nutritive ratios are calculated from the analyses made in the experiments taken, together with other analyses of like materials, as used in New England. The more nitrogenous materials are, of course, those richest in protein or "flesh formers," while the more carbonaceous are those poorer in protein and having larger proportions of the fuel ingredients, i. e., fats, and especially the carbohydrates. The former, with smaller nutritive ratios (ratio of protein to fuel ingredients), tend to make narrow rations, while the latter make wide rations.

CLASSIFICATION OF FEEDING STUFFS USED IN THESE TESTS.

Nitrogenous Feeding Stuffs—Rich in Protein.	Nutritive Ratio.	Carbonaceous Feeding Stuffs—Poor in Protein.	Nutritive Ratio.
Cotton seed meal, - -	1.3	Corn fodder or ensilage,	8.5
Linseed meal, - -	1.8	Corn meal, - - -	9.8
Cream gluten, - -	2.1	Corn and cob meal, -	9.9
Gluten meal, - - -	2.4	Roots (turnips, etc.), -	9.5
Malt sprouts, - -	2.5	Potatoes, - - -	13.0
Pea meal, - - -	3.2	Hay, mixed grasses, -	10.9
Gluten feed, - - -	4.0	Red-top hay, - -	10.8
Wheat bran, - - -	4.0	Timothy hay, - -	13.0
Wheat middlings, - -	4.2	Timothy and red-top hay,	11.5
Clover hay, - - -	5.1	Oat hay, - - -	11.0
Rowen hay, - - -	5.3	Corn stover, - - -	17.4

In 1892–93 sixteen herds were visited and a five-days' test was made with each. In 1893–94 six herds were visited, and in four instances the time of study of the feeding, management, and products of each herd was extended to twelve days. As soon as the analyses could be made, the amounts of actual nutrients in the rations fed were calculated, and in three cases other rations were

suggested. The feed was gradually changed to the suggested ration with these three herds, and after four weeks from the close of the first test another twelve-days' test was made with the new ration.

In 1894–95 four herds were studied on the same plan as in the longer studies made the previous winter, except that the length of time between the two tests, on the same herd, was shortened to two weeks.

In 1895–96 two herds were studied on the same plan as those of the previous winter, except that the time between tests was reduced to nine days. In one of these cases the herd was fed a very large ration of protein with an unusually narrow nutritive ratio.

RATION FOR A MILCH COW.

A proper ration for a milch cow would furnish the nutrients needed to form the materials of the body and the milk, and the energy required to do the necessary muscular work and keep the body warm. Just what weights of digestible protein, fats, and carbohydrates will, as a general average, meet these needs is a matter of uncertainty. The following rations have been suggested as guides in the practical feeding of milch cows of a live weight of 1000 pounds. It is to be remembered, however, that a small cow giving a good amount of milk may need more than a much larger cow producing less. It is worth noting that in Germany the heavier breeds of cows are more commonly and the lighter breeds—like the Jerseys—less commonly used for dairy purposes than with us. Such light-weight cows may, however, demand as much food and as much protein for large milk production as larger cows.

	German Standards.					Standard tentatively suggested by the Station.
	Wolff's Standard for 1000 lbs. live weight.	Lehmann's for a Cow Giving				
		11 lbs. Milk Daily.	16½ lbs. Milk Daily.	22 lbs. Milk Daily.	27½ lbs. Milk Daily.	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Organic matter, - -	25.0	25.0	27.0	29.0	32.0	25.0
Digestible protein, -	2.5	1.6	2.0	2.5	3.3	2.5
Digestible fats, - -	.4	.3	.4	.5	.8	.5 to .8
Digestible carbohydrates, - - -	12.5	10.0	11.0	13.0	13.0	13 to 12
	Cal.	Cal.	Cal.	Cal.	Cal.	Cal.
Fuel value, - - -	29600	22850	25850	30950	33700	31000
Nutritive ratio, - -	1:5.4	1:6.7	1:6.0	1:5.7	1:4.5	1:5.6

The ration suggested by the Station is founded upon the standard of Wolff, with allowance for the abundance and cheapness of foods of high fuel value, i. e., those rich in carbohydrates and fats, in the United States. The experience of the last two years would, however, indicate that, in general, it is more profitable to feed a cow in "the flush" rather more protein than the suggested ration calls for. The very decided trend of these experiments is toward nitrogenous feeding for large milk production. The German standards of Lehmann, which are later than those of Wolff, give expression to the same tendency in the results of late experience and experiment in Germany.

GENERAL CONCLUSIONS.

The cost of producing milk and butter depends largely upon the kind of cows and their condition as regards time from calving. Many of the individual cows in these tests were not returning the cost of feed. One of the first things our dairymen need to do is to make a closer study of the individual animals of their herds and to reject the unprofitable ones. The relative productiveness of cows can be easily learned by the use of the Babcock test, together with the daily weighing of the milk. In these tests the cost of the ration depended largely upon the proportion of the cheaper coarse fodders like corn silage, corn stover, clover hay, oat hay, and second quality ordinary hay, which went to make up the total coarse fodders of the ration. The better grades of hay, such as timothy and red-top, were among the most expensive feeding stuffs used. When good hay sells for from fifteen to eighteen dollars per ton it is generally more profitable to sell than to feed to dairy cows.

A liberal proportion of the nitrogenous grain feeds tended to lessen the total cost of the ration in the majority of the cases, while the net cost was greatly lessened by their use. The nitrogenous (protein) feeding stuffs like clovers, cotton seed, linseed and gluten meals, should be more extensively used as dairy feeds. These feeds have been shown to exert a greater influence on the quantity and quality of animal products than corn and even wheat feeds, and when the manure is carefully saved they are of great value for keeping up the fertility of the farm.

Pt II

INVESTIGATIONS ON METABOLISM IN THE HUMAN ORGANISM.

PRELIMINARY ACCOUNT OF EXPERIMENTS ON THE INCOME AND OUTGO OF THE BODY AND THE EFFECTS OF DIFFERENT DIETS.

BY W. O. ATWATER, C. D. WOODS AND F. G. BENEDICT.

In the year 1892 the first steps were taken at Wesleyan University toward the development of an apparatus for measuring the income and outgo of the animal body. It was proposed to study, among other things, the application of the law of the conservation of energy in the animal organism and plans were made for experiments with men. The investigation was undertaken jointly by Professors Atwater and Rosa, and was conducted under the patronage of the University and in connection with the Storrs Experiment Station. In the report of the Station for 1893 the purpose of the inquiry was stated in the following language:

> "Research upon nutrition has brought us to the point where the study of the application of the laws of the conservation of matter and of energy in the living organism are essential. That is to say, we must be able to determine the balance of income and outgo of the body, and this balance must be expressed both in terms of matter and of energy. For this purpose a respiration calorimeter is being devised. This is an apparatus in which an animal or a man may be placed for a number of hours or days and the amounts and composition of the food and drink and inhaled air; the amounts and composition of the excreta, solid, liquid and gaseous; the potential energy of the materials taken into the body and given off from it; the quantity of heat radiated from the body; and the mechanical equivalent of the muscular work done, are all to be measured. The experimenting is complicated, costly and time-consuming. The results already obtained are, however, very encouraging in their promise of future success."

Fortunately for the success of the enterprise the interest of the trustees and officers of Wesleyan University, especially in the purely scientific phases of the inquiry, was such that laboratory rooms and appliances were made available, as

were also the services of the University mechanician, Mr. O. S. Blakeslee, and the use of the mechanical laboratory, which is especially fitted for the construction of scientific apparatus. With these facilities and a portion of the funds of the Experiment Station the work progressed so far that the success of the enterprise seemed reasonably assured. The need of much larger sums for the experimental work, however, became more and more pressing. Here again the research met with good fortune. In the year 1894 a provision was made by act of Congress for an inquiry into the food and nutrition of the people of the United States. The responsibility for the inquiry is vested in the Secretary of Agriculture, by whom it was assigned to the Office of Experiment Stations of the Department of Agriculture, and the immediate charge was placed in the hands of the Director of the Storrs Experiment Station as Special Agent of the Department. It was considered that a research not only germane, but fundamental to such an inquiry, might be appropriately aided from this fund, though the amount which could be utilized for the purpose was small. In 1895 the Legislature of Connecticut provided a special annual appropriation to be expended by the Storrs Experiment Station for food inquiries. The resources of the Station for this purpose were thus increased, and with the supplement from the General Government and the private aid referred to, it has been possible to greatly enlarge the scope of the inquiry and to prosecute the work in a manner which would otherwise have been entirely out of the question. Indeed this may be regarded as one of that class of cases in which the higher scientific research has been favored by a happy combination of private and public support in such a way as not only to insure the greatest economy in the use of money and other resources, but also to promise a valuable outcome.

The inquiry has thus assumed such form that it naturally divides itself in two parts. These have to do respectively with the metabolism of matter, and the metabolism and conservation of energy.

The purpose of the present article is to give a brief preliminary account of so much of the work thus far done as bears directly upon the metabolism of matter. The results obtained

regarding the balance of income and outgo of energy are to be held until some changes, which experience has indicated to be desirable in the apparatus and methods, can be made, and the results already obtained can be verified and new ones added.

In the devising and elaborating of the apparatus, as well as in the actual carrying out of the experimental work, Prof. E. B. Rosa of Wesleyan University has had an active share. Upon him has devolved especially the devising and care of that part of the apparatus and inquiry which has to do with its physical side, including the measurement of the heat radiated from the body. The chemical side of the inquiry, and with it the determinations of the potential energy of the products of income and outgo have been superintended by Prof. Atwater.

Besides the names of the authors of the present report those of the collaborators should be mentioned. Mr. A. W. Smith had much to do with the development of the apparatus, especially the physical side, and with the carrying out of the experiments. He was himself the subject of the last of the four experiments here described. Dr. O. F. Tower has done a large amount of the chemical work and has been otherwise associated with the experiments. He was the subject of the third experiment of the four recounted here. Mr. A. P. Bryant rendered valuable assistance in the chemical part of the inquiry. Mr. H. M. Burr had the charge of the preparation of the food for the experiments and has had a large share in the work of analysis.

It is now expected that the part of the work which bears more directly upon the conservation of energy will be published hereafter under the joint authorship of Professors Atwater and Rosa.

The following is an abbreviated description of the apparatus and methods used and of the results of four experiments upon the income and outgo of carbon and nitrogen. In each of the experiments the subject remained for several days inside the respiration chamber, the periods being from two and one-fourth to twelve days.

A more detailed report of the experiments here described has been made to the Department of Agriculture for publication in a Bulletin of the Office of Experiment Stations. The

present account is taken from that report by arrangement with the Department. Since the Bulletins of the Department are distributed among institutions and to persons interested in the details of such inquiries it will suffice here to give a condensed statement of the more important facts.

APPARATUS.

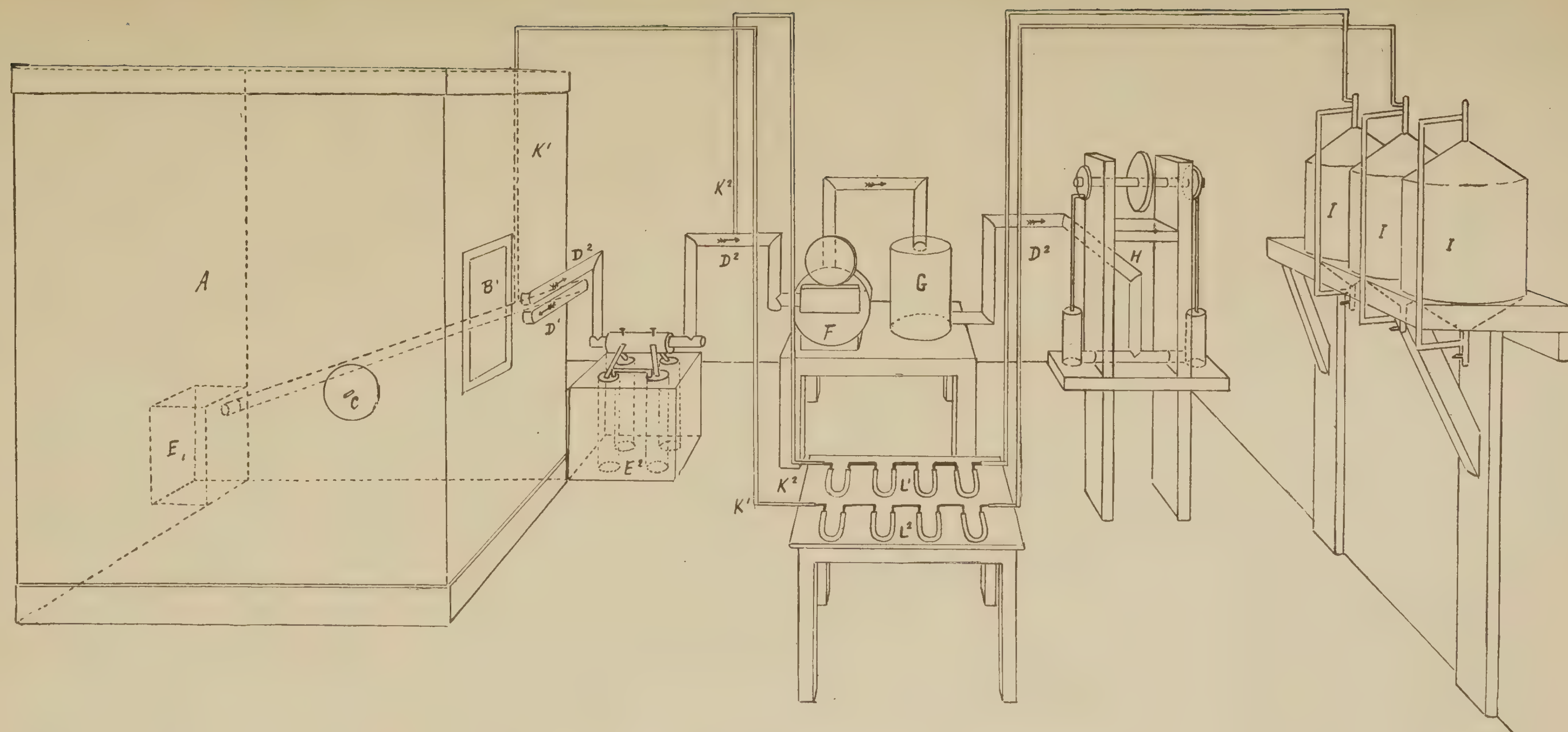
The apparatus consists essentially of a respiration chamber in which the subject stays during the experiment, and, with this, appliances for maintaining a current of air through the respiration chamber and for measuring and analyzing this ventilating current of air. There are also appliances for measuring the heat given off from the body.

The general arrangement will be made clear by the outline sketch on the opposite page. This shows the relations of the several parts, although numerous details of apparatus and machinery are omitted, and the parts are not drawn to scale nor are they shown in exactly the relative positions in which they were actually placed.

So far as concerns the experiments herewith reported, which are of the nature of the common respiration experiments, the apparatus may be considered as a modification of the well known Pettenkofer apparatus. The general principle is the same. The arrangements for maintaining the current of air and for measuring its volume and analyzing portions are, however, quite different from those which have been commonly used with the Pettenkofer apparatus.

RESPIRATION CHAMBER.

This is a room or box in which a man may live comfortably during the period of an experiment. The inside dimensions are: length, 2.15 m. (7 ft.), width, 1.22 m. (4 ft.); height, 1.92 m. (6 ft. 4 in.). It is provided with conveniences for sitting, sleeping, eating, and working, as well as arrangements for ventilation and for the study of the respiratory products. The chamber consists, in fact, of three concentric boxes, the inner one of metal and the two outer ones of wood. The inside volume is approximately 4.7 cubic meters. An opening in the front end of the metal chamber, 70 cm. high and 49 cm. wide (27½ x 19⅜ in.), serves both the purpose of a window and that of a door for entrance and exit.



OUTLINE SKETCH OF RESPIRATION APPARATUS.

A. Respiration chamber.
B. Glass door.
C. Food aperture.
D_1. Pipe for incoming air to ventilate chamber.
D_2. Pipe for outgoing air.
E_1. Refrigerating apparatus for cooling the incoming air.
E_2. Refrigerating apparatus for cooling the outgoing air.
F. Meter for measuring air current.
G. Tension equalizer for air current.
H. Air pump for drawing air through the whole apparatus.
J. J. J. Aspirators for drawing samples of air for analyses.
K_1. Tube for sample of incoming air for analyses.
K_2. Tube for sample of outgoing air for analyses.
L_1 and L_2. Absorption tubes for analyses of the samples of outgoing and incoming air.

Numerous passages through the wooden and metal walls are needed for tubes to convey the ventilating current of air; wires for various electric connections; and the aperture ("food tube") for passing the food and drink into the apparatus and taking out the solid and liquid excretory products. The tubes through which the currents of air ("ventilating tubes") pass have an internal diameter of 4 cm. (1½ in.). The food aperture is of copper and has an internal diameter of 15 cm. (6 in.). It is situated on the left side of the apparatus (see diagram) and is provided with a cap at each end. The outer cap is attached by a screw so that it may be closed air tight. In putting in the food and other materials the cap is taken off, the receptacle containing the food is placed in the tube and the cap put on again. A signal is then given to the man inside who removes the inner cap and takes out the receptacle. The materials from within are passed out in corresponding manner. In this way there is no danger of ingress or egress of any considerable quantity of air.

A wet and dry bulb hygrometer, capable of being read to hundredths of a degree centigrade is hung in the rear of the chamber and observations are made by the occupant, generally at intervals of two hours, during the period of the experiment. These observations are reported by the telephone and show the hygrometic condition of the air inside the apparatus.

The furniture used in the experiments here reported consisted of a light, folding canvas cot bed; a folding chair; and a folding table. Such clothing and bedding as were needed for comfort were taken in by the man at the beginning of the experiment and small articles were passed in and out through the food tube at convenient times. The floor was protected by carpeting. The amounts of water held by the furniture and clothing, etc., were determined as accurately as practicable by weighings at the beginning and end of each experiment.

APPARATUS FOR MEASURING AIR AND TAKING SAMPLES FOR ANALYSIS.

The essential features of a respiration experiment are the maintenance of a proper current of air, the accurate measurement of its volume and the determination of the respiratory products. The air was drawn through the apparatus by means

of specially devised air pumps, its total current was measured by a gas meter especially constructed for the purpose, the samples of incoming and outgoing air were drawn by aspirators, the carbon dioxide in the sample was determined by absorption by soda lime, and the water by absorption by sulphuric acid. The volume of air passing through the apparatus varied from 50 to 75 liters per minute. The longest experiment was of 12 days duration, and was made with an air current of approximately 55 liters per minute. It is desirable to have the incoming current of air as dry as possible. This drying was easily accomplished by surrounding a portion of the pipe through which it passed with a freezing mixture of salt and ice.

The samples of air for analysis were drawn by means of aspirators, two of which had previously served for the calibration of the meter. These aspirators, three in number, are cylinders of galvanized iron, standing upright, with conical ends. The cylinders are 56 cm. (22 in.) in diameter and 46 cm. (18 in.) in height, exclusive of cones which form the ends. To fill the aspirators the water is introduced near the top while the air passes out from the upper neck. In drawing the samples of air the water passes out from the lower while the air to be measured enters the upper neck. Horizontal tubes connect the two necks with an upright glass tube on the side of the aspirator. This serves as a gauge and shows the height of the water. It is accurately marked at the top and bottom and thus permits the drawing off of a definite quantity of water and consequently the accurate measurement of the volume. In taking a sample the aspirator is first filled to the mark indicated on the water gauge outside, the connection is then made by a 3-way cock with the tube through which the sample of air is drawn from the main current.

APPARATUS FOR DETERMINING THE CARBON DIOXIDE AND WATER IN SAMPLES OF AIR.

The constituents of the air determined in the experiments described beyond were carbon dioxide and aqueous vapor. The determinations are made by absorbents, soda lime for the former and sulphuric acid for the latter. These reagents are contained in ordinary glass U tubes. The device above referred to for removing the moisture from the main

air current by cooling to about -17° centigrade leaves a small and reasonably uniform amount of moisture and thus greatly facilitates the determination of the latter in the samples analyzed. Four U tubes are used for the absorbing, two for the carbon dioxide and two for the water of each sample. These tubes are connected in series and conveniently supported in a nearly horizontal position while the air is passing through. For weighing they are separated and hung by loops of platinum or aluminum wire in the balance.

Freezing Apparatus.—In our experience during the several years in which the apparatus and experimental methods here used have been in process of elaboration it has been found very desirable to have the air enter the respiration chamber as dry as possible. It was with this fact in view that the plan was first adopted for freezing the air as it came from outside before it entered the chamber. The freezer used for this purpose consisted practically of two large U tubes of copper. These are connected with each other and with the pipe through which flows the current of incoming air. They stand upright in a wooden box which is kept filled with a freezing mixture of salt and ice. In this way the current of air has to pass through nearly 12 ft. of copper tubing which is covered by the freezing mixture. This method of removing the excess of moisture from the air before it enters the chamber proved so satisfactory as to lead to its adoption in quantitative determinations of the moisture in the outgoing air. For this purpose, however, a somewhat more complicated freezer is necessitated by the fact that the water which it collects must be accurately weighed.

The use of ice and salt for freezing proved unsatisfactory because of the trouble of frequent renewal, the expense for material and labor, which was not inconsiderable, the difficulty of getting a satisfactory low temperature and especially the impossibility of maintaining a constant temperature. For the later experiments we have adopted the plan of immersing the freezers in a brine cooled by the expansion of ammonia gas. For a cooling apparatus we have found the so-called "Economical Ice Machine" made by the Atlantic Refrigerating Company, of Springfield, Mass., simple, easily operated, and entirely efficient for the purpose.

METHODS OF ANALYSIS.

The methods used for the analysis of the food and feces were in general those adopted by the Association of Official Agricultural Chemists. Certain deviations were introduced where necessary. The methods used for the analyses of urine were such as are commonly followed. The methods employed in the determinations of water and carbon dioxide in the incoming and outgoing air involved some special deviations from those ordinarily in use.

PREPARATION OF SAMPLES.

Meats, vegetables, and other materials containing considerable water require to be chopped or otherwise comminuted and partially dried before grinding. For comminuting meats we use an ordinary sausage grinder. The "Excelsior Meat Grinder" has proved very satisfactory for this purpose. Potatoes, when fresh, are cut in thin slices with a knife. When cooked they are simply mashed. Bread is easily sliced, broken, and pulverized sufficiently for the purpose. The samples when too moist for grinding were partially dried; the material in the original or partially dried form was sampled and ground, first in an ordinary "Excelsior Mill," afterwards in a Maercker-Dreefs Mill, by which it is easily reduced to an impalpable powder.

CARBON DIOXIDE AND WATER IN AIR.

In experiments of the class to which these belong the respiratory products commonly determined are carbon dioxide, water and volatile organic compounds.

The determination of carbon dioxide is most essential and is of course always attempted. The experience of a number of experimenters during the past twenty-five years implies that the difficulties in the way of fairly accurate results are not insuperable. The carbon dioxide given off in respiration is quickly diffused through the air and readily conveyed away by the ventilation current so that the accurate measurement of that current and determination of the percentage of carbon dioxide suffices for the ordinary purposes of experiment. If, therefore, the accurate measuring and sampling of the air are provided for, a correct method for determining the carbon dioxide in the sample is all that is needed in addition.

The accurate determination of water has been found less easy. The difficulty appears to rest not so much in the determination of moisture in the current of air as in the getting of all the moisture into the current. The water to be determined is the whole given off from the body of the subject in the respiration chamber, less the amount removed in feces and urine. Practically this means the water exhaled through the lungs and skin. For our present purpose it may be designated as water of exhalation, and taken as including the water of respiration from the lungs and that of perspiration from the skin.

While the efforts to obtain all the exhalation water in the current of air coming out of the respiration chamber were not entirely successful, not a little labor was devoted to the study of ways to determine accurately the amounts of both carbon dioxide and water in the currents. The success here was on the whole decidedly gratifying. Various reagents for absorption and methods of manipulation were tried. We finally settled upon the plan of cooling both the incoming and outgoing currents of air to remove the larger part of the water and passing samples over sulphuric acid to determine the rest. For determining the carbon dioxide we have had better success with soda lime as an absorbent than with either potassium hydroxide, solid or in solution, or barium hydroxide solution by the well known Pettenkofer method.

Determination of water.—As explained above the most of the water of both the incoming and outgoing currents of air was removed in passing through the freezers, of which there was one series of two freezers for each current. The water condensed from the incoming current was not weighed, that condensed from the outgoing current was weighed. The amount remaining in the air after it had left the freezers was determined by passing a sample over sulphuric acid in U tubes.

Absorption of carbon dioxide.—As above stated, soda lime has proven the most satisfactory reagent, but it must, however, have the proper proportions of soda lime and water to fit it for the purpose. The presence of a certain amount of moisture in the soda lime is essential to the complete absorption of the CO_2.

The tests of the accuracy of the methods thus described for determining the H_2O and CO_2 in the air from the respiration

chamber were sufficient to convince us of their reliability. Plans are made, however, for more extended tests of this kind, after the introduction of changes in the apparatus which are intended to secure more accurate measurement and sampling of the air than we were able to secure with a gas meter and aspirators.

PLAN AND METHOD OF EXPERIMENTS.

In the account of experiments here given the balance of energy is omitted for the reason already explained, and only the income and outgo of matter are considered. The difficulties in the determination of the total water of exhalation, were not entirely surmounted when the experiments were made. Hence the amount of water in the outgo and with it the hydrogen balance are omitted. As the main purpose of the experiments was to gather experience in the manipulation of the apparatus and the treatment of men in the respiration chamber the determination of other elements was not attempted. Accordingly the factors actually determined and here reported are:

Income:—Food, drink and their content of nitrogen, carbon, protein (N. x 6.25), fats (ether extract), carbohydrates (by difference), mineral matter (ash).

Outgo:—Respiratory products; carbon dioxide and its content of carbon.

Feces: nitrogen, carbon, protein (N. x 6.25), fats (ether extract), carbohydrates (by difference), mineral matters (ash).

Urine: nitrogen, carbon.

Such experiments as these, which include measurement of the income of the food and drink and of the outgo of the excretory products, including those of respiration, are commonly called respiration experiments. They necessitated, however, in each case a digestion experiment, that is to say, a comparison of the food consumed and the undigested residue which gives the amounts actually digested.

DIET, MEALS.—DAILY RATIONS.

In these experiments the effort was made to have the conditions as nearly normal as possible. To this end it was essential that—

1. The diet be such as to agree with the subject.

2. The quantities of nutrients be such as to meet the actual needs of the body under the conditions in which the subject was placed during the experiment.

Meals were eaten three times daily at regular hours, thus conforming as far as possible to ordinary custom. Drinking water was allowed at all times, the weight used, however, being carefully noted. The freedom allowed in the selection of diet materially added, we believe, to the success of the experiment, although the number of different materials, including delicacies, made the analyses quite laborious.

The entire charge of weighing and cooking the food and taking of samples for analyses was placed in the hands of one individual. Indeed, throughout the whole of our experimenting the effort has been to have the observers carefully trained and unfettered by a multiplicity of duties, and the work shaped in systematic routine, in the hope that minor errors, which are almost impossible to avoid entirely, might thus be reduced to a minimum.

COLLECTING, PRESERVING AND SAMPLING OF EXCRETORY PRODUCTS.

One desideratum in experiments of this kind is to keep the air in the chamber as free from disagreeable odors as possible. To this end the feces and urine were collected in receptacles provided for the purpose, the receptacles being closed immediately, and passed out through the food aperture after they had come into temperature equilibrium with the air in the chamber. It was found that the unpleasant odor could be almost instantly destroyed by the use of an ordinary toilet "atomizing" bottle by which minute quantities of a commercial preparation, presumably containing eucalyptol, was diffused into the air of the chamber. The feces were collected as described in the article on Digestion Experiments beyond.

The collection and preservation of the urine for analysis requires especial attention. In these experiments the bladder was emptied every morning at six o'clock. All the urine voided between that hour and the next morning at the same hour was taken as the urine for that day. Each day's urine was carefully weighed, thymol being added as a preserving agent.

DAILY ROUTINE OF THE EXPERIMENTS.

The digestion experiment which was made with each respiration experiment commenced two or three days before the latter, but both ended at the same time. On the second or third day of the digestion experiment the subject entered the respiration chamber, but, in order to insure normal conditions, the respiration experiment did not begin until six hours after he had entered. This allowed the man an opportunity for arranging his furniture, the hygrometer, thermometer, and other apparatus in the room, and permitted the establishment of the needed equilibrium of temperature and moisture content in the chamber preparatory to the respiration experiment itself.

The occupants of the chamber passed the time in such ways as were in general most agreeable under the circumstances. They observed regular hours of eating and sleeping. There was, of course, almost no opportunity for exercise. In the last experiment, however, a special arrangement was made for vigorous muscular labor in lifting and lowering a weight suspended from a pulley. Abundant opportunity was given for reading, considerable conversation was held between the occupant and the men who did the work outside, and the monotony was also relieved from time to time by visitors.

The amount of labor involved in these experiments is very considerable. The work goes on day and night. Relays for day and night work were, of course, necessary. During the day a force of five or six persons was generally employed. During the night, when the occupant of the chamber was asleep, the force was reduced to three.

A brief description of the routine of one day will perhaps help to a better understanding of the way in which the experiment is carried out. The night force of operators was relieved at seven o'clock A. M. At that time the subject was awake and ready for breakfast. The assistant, who had charge of the preparation and cooking of the food, prepared the breakfast; the chemist of the night force changed the system of U tubes for analysis of the air. The day chemist proceeded to start the passage of the air through the fresh system of tubes, and then weighed the system which had just been removed; the readings of the meter, by which the ventilating current of air was measured, and of temperature, barometric pressure, etc., were

made. The subject passed out the liquid and solid excreta. The readings of the hygrometer and thermometer inside the apparatus were taken by the subject on rising, and the observations were repeated once in two hours throughout the day. Naturally, the inquiry regarding the subject's physical condition, and any changes needed, received early attention in the morning.

Breakfast was ordinarily served at about half-past seven o'clock, dinner at about half-past twelve o'clock, and supper at six o'clock. Drinking water was given whenever desired, its weight and temperature being noted.

The freezing apparatus required repacking with ice and salt about once in two hours during the day and night; the rate of flow of water through the aspirators by which the samples of air for analysis were drawn was regulated every half-hour. The temperature of the air of the meter was recorded hourly. The freezers through which the outgoing air passed were changed once in twelve hours, and the water condensed in them was weighed. The absorption tubes for the water and carbon dioxide of the air samples were changed once in six hours, at which time the temperature of the aspirators, the temperature of the meter, and the readings of the meter and of the air pump register were recorded.

Concurrently with all of these operations the analytical work was carried on and completed as rapidly as possible.

When a respiration experiment lasts but three or four days, the prosecution of all this work is not extremely difficult, provided the force of operators is sufficiently large and well organized, but when it must be continued for twelve days, as was the case in the last experiment, the difficulty is gradually increased. When it is considered that both night and day forces, as well as the subject, are placed under quite unusual conditions, we deem ourselves especially fortunate in having been able to continue the experiment successfully for so long a period.

In this connection we take pleasure in expressing our appreciation of the courtesy of the Electric Light and Power Company of Middletown, by whom a constant supply of power was furnished, so that no one of the experiments was interrupted.

INDIVIDUAL EXPERIMENTS.

In the following accounts of the individual respiration experiments reference is made to digestion experiments. The latter were made in connection with the former, but the results are detailed in the article on digestion experiments beyond.

RESPIRATION EXPERIMENTS NOS. 1 AND 2.

The daily routine and details of the first two experiments were, from the nature of the case, much simpler than those of the later experiments. Improvements were constantly being suggested and adopted as the work progressed. The analysis of respiratory products are, we believe, sufficiently accurate to warrant their publication. However, it is only fair to state that these two experiments in particular are looked upon as decidedly preliminary. When it is considered that the experience was a new one to both the subject and to the observers, and that time was required to get the machinery in smooth running order, the tentative nature of these two experiments is apparent. The kinds and amounts of food were as follows:

Daily Menu. Respiration experiment No. 1. Digestion experiment No. 11.

The digestion experiment continued 4⅔ days, of which the respiration experiment covered 2⅓ days.

Breakfast.	Grams.	*Dinner.*	Grams.	*Supper.*	Grams.
Eggs, -	- about 100	Cooked meat,	- 121	Cheese, -	- 75
Butter, -	- 15	Butter, -	- 20	Milk, - -	- 600
Milk, - -	- 100	Milk, - -	- 300	Milk crackers,	- 100
Bread, -	- 100	Bread, -	- 150		
Sugar, -	- 20	Potatoes, -	- 150		
Coffee,	- about 300				

28⅖ grams, approximately, equal one ounce.

Daily Menu. Respiration experiment No. 2. Digestion experiment No. 12.

The digestion experiment continued 4⅔ days, of which the respiration experiment covered 2⅓ days.

Breakfast.	Grams.	*Dinner.*	Grams.	*Supper.*	Grams.
Eggs, -	- about 100	Cooked meat,	- 100	Cheese, -	- 75
Butter, -	- 15	Butter, -	- 20	Milk, - -	- 100
Milk, - -	- 100	Milk, - -	- 300	Milk crackers,	- 100
Bread, -	- 100	Bread, -	- 150	Sugar, - -	- 20
Sugar, -	- 20	Potatoes, -	- 150	Coffee, -	- about 300
Coffee,	- about 300				

RESPIRATION EXPERIMENT NO. 3.

In the third experiment the methods of operation had been considerably elaborated and improved upon, the force of observers enlarged, while the experience gained in the two former experiments added materially to its successful completion. The diet in the experiment was considerably more varied than in those preceding. The subject selected his own diet, and in order to avoid monotony, varied the daily menu by having canned peaches one day for dinner and supper and canned pears the next.

Daily Menu. Respiration experiment No. 3. Digestion experiment No. 13.

The digestion experiment continued 8⅓ days, of which the respiration experiment covered the last 5 days.

Breakfast.	Grams.	*Dinner.*	Grams.	*Supper.*	Grams.
Eggs, - -	113	Cooked beef, -	95	Milk, - - -	500
Butter, - -	10	Butter, - -	10	Bread, - -	125
Milk, - - -	100	Milk, - - -	60	Sugar, - -	10
Bread, - -	75	Bread, - -	75	Peaches or pears,	200
Sugar, - -	20	Sugar, - -	20		
Apples, - -	85	Potatoes, - -	130		
Tea or coffee, about	300	Peaches or pears,	150		
		Tea or coffee, about	300		

RESPIRATION EXPERIMENT NO. 4.

The last experiment is more detailed than the previous ones and the observations were more thoroughly systematized. The interest and enthusiasm of the gentleman who acted as subject added materially to the success of the experiment and permitted the collection of much more valuable data than would otherwise have been possible.

Daily Menu. Respiration experiment No. 4. Digestion experiment No. 14.

The digestion experiment continued during 16⅔ days, of which the respiration experiment covered the last 12 days.

Breakfast.	Grams.	*Dinner.*	Grams.	*Supper.*	Grams.
White bread, -	75	Cooked beef, -	96	Milk, - - -	500
Oatmeal, - -	40	White bread, -	75	Brown bread, -	250
Beans, - -	120	Mashed potatoes, -	100		
Milk, - - -	150	Butter, - - -	30		
Butter, - -	15	Apples, - -	125		
Sugar, - -	20				

The experiment continued for 12 days. It was divided into the equivalent of 4 periods of 3 days each, though actually there were 5 periods. The first was 1⅝ and the fifth, 1⅜ days, making together 3 days. The first short period was regarded as introductory. During this period, as during the fifth, the subject did not engage in any muscular or mental work except such reading and very slight physical exercise as were needed to pass away the time comfortably.

The second period, which was the first experimental period proper, was devoted to mental labor. The subject engaged for eight hours a day or thereabouts in the active work of either calculating results of previous experiments or studying a German treatise on physics. The mental application was as intense as it could well be made. The third period, which was the second experimental period, likewise of three days duration, was given to nearly absolute rest. During this time the subject was as quiet as possible, neither exercising the muscles nor working with the brain. During a larger part of the time he reclined upon the bed. Of course it was impossible to avoid all intellectual activity, but the amount was made as small as practicable. The fourth period, or third experimental period, was one of intense muscular activity. A pulley was attached to the top of the chamber. Over this passed a cord. One end of the cord was attached to a block of iron weighing 5.7 kilograms. To the other end was attached a handle. This provided for active exercise not only of the arms, but also of the legs and other parts of the body. The whole arrangement was quite similar to some of the forms of apparatus very commonly used for gymnastic exercise. With this the subject worked severely for eight hours on each of the three days so that at the end of each day's work he was thoroughly tired. He perspired very freely during the working hours. This last experimental period was followed by the final short period of rest.

In examining the detailed results of the experiments it is interesting to note that, whatever had been the occupation during the day a period of six hours' rest was sufficient to bring the elimination of carbon dioxide back to a normal quantity. Even after the large elimination of carbonic acid which accompanied each period of hard muscular work, amounting at times

to 500 grams for six hours, the simple return to rest was followed almost immediately by a return to the normal elimination of CO_2.

In the case of the elimination of nitrogen in the urine, however, the increase consequent upon hard muscular work, or the decrease when the body was in a state of rest, did not manifest itself until some hours after the muscular work began or ended. This interval, during which the excretion of nitrogen lags behind the metabolism, and which we have got in the way of calling the "nitrogen lag," may be assumed to be longer or shorter. For instance, it may be supposed that the nitrogen metabolized in a given day beginning at six in the morning will be excreted in the urine of the day beginning the following noon, thus allowing a lag of six hours. This assumption was actually made in the calculations of nitrogen balance in one of the experiments here reported. In another experiment a lag of twelve hours was allowed for. As explained in the discussion of the details of respiration experiment No. 4 beyond, thirty hours may be a more nearly correct period, and estimates are made accordingly.

We have been unable to find data for judging at all accurately as to the length of this interval of lag. For that matter it is doubtless impossible to make any accurate estimate, for there is no assurance that either exactly the same nitrogen or the same amount of nitrogen that is metabolized during a given period will be contained in the urine of any other period of equal length unless both periods are very long. Sufficient evidence of this is found in the fluctuations in the daily nitrogen excretion in the experiments herewith reported, when the diet and other conditions were reasonably uniform.

RESULTS OF THE RESPIRATION EXPERIMENTS.

The detailed results of these experiments are given in the Bulletin of the Department of Agriculture above referred to, in which the methods of calculating the results from the numerous data are more or less fully explained. It will, therefore, suffice here to briefly recapitulate the principal data. Those for ventilation and CO_2 exhalation are epitomized in table 9 beyond. Those for nitrogen and carbon balance are summarized in tables 7 and 8 herewith.

TABLE 7.

Nitrogen balance and estimated gain and loss of protein in respiration experiments.

The figures of column C are obtained by subtracting those in B from those in A. In like manner E = A — (B + D) or E = C — D.

DATE.	NITROGEN.					Estimated Gain (+) or Loss (—) of Protein.*	Corresp'd'g Gain (+) or Loss (—) of Nitrogenous Tissue.†
	A	B	C	D	E		
	In Food.	In Feces.	Digested.	In Urine.	Stored (+) or Lost (—).		
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Experiment No. 1. (E. O.)							
Feb. 17–18, - - -	22.7	.9	21.8	20.2	+1.6	+10.0	+43.3
Feb. 18–19, - - -	22.7	.9	21.8	19.0	+2.8	+17.5	+75.8
Feb. 19 (¼ day), - -	10.1	.3	9.8	3.8	+6.0	+37.5	+162.5
Total, 2¼ days, -	55.5	2.1	53.4	43.0	+10.4	+65.0	+281.6
Experiment No. 2. (E. O.)							
Feb. 26–27, - - -	19.2	1.6	17.6	18.6	—1.0	—6.3	—27.3
Feb. 27–28, - - -	19.2	1.6	17.6	17.5	+0.1	+0.6	+2.6
Feb. 28 (¼ day), - -	4.5	.5	4.0	3.6	+0.4	+2.5	+10.8
Total, 2¼ days, -	42.9	3.7	39.2	39.7	—0.5	—3.2	—13.9
Experiment No. 3. (O. F. T.)							
Mch. 16–17, - -	16.1	.9	15.2	12.7	+2.5	+15.6	+67.6
Mch. 17–18, - -	16.1	.9	15.2	13.5	+1.7	+10.6	+45.9
Mch. 18–19, - -	16.1	.9	15.2	13.6	+1.6	+10.0	+43.3
Mch. 19–20, - -	16.1	.9	15.2	13.7	+1.5	+9.4	+40.7
Mch. 20–21, - -	16.1	.9	15.2	15.2	0.0	0.0	0.0
Total, 5 days, - -	80.5	4.5	76.0	68.7	+7.3	+45.6	+197.5
Experiment No. 4. (A. W. S.)							
Mch. 23 (⅝ day), -	5.0	.9	4.1	9.1	—5.0	—31.3	—135.6
Mch. 24–25, - -	16.2	1.4	14.8	14.1	+0.7	+4.4	+19.1
Mch. 25–26, - -	16.2	1.4	14.8	13.1	+1.7	+10.6	+45.9
Mch. 26–27, - -	16.2	1.4	14.8	13.7	+1.1	+6.7	+29.0
Mch. 27–28, - -	16.2	1.4	14.8	12.6	+2.2	+13.7	+59.4
Mch. 28–29, - -	16.2	1.4	14.8	11.9	+2.9	+18.1	+78.4
Mch. 29-30, - -	16.2	1.4	14.8	12.4	+2.4	+15.0	+65.0
Mch. 30–31, - -	16.2	1.4	14.8	13.1	+1.7	+10.6	+45.9
Mch. 31–Apr. 1, - -	16.2	1.4	14.8	11.7	+3.1	+19.4	+84.1
Apr. 1–2, - - -	16.2	1.4	14.8	16.4	—1.6	—10.0	—43.3
Apr. 2–3, - - -	16.2	1.4	14.8	14.3	+0.5	+3.1	+13.4
Apr. 3–4, - - -	16.2	1.4	14.8	16.1	—1.3	—8.1	—35.1
Apr. 4 (⅜ day), -	11.2	.5	10.7	5.3	+5.4	+33.7	+146.0
Total, 12 days, - -	194.4	16.8	177.6	163.8	+13.8	+85.9	+372.2

* N. multiplied by 6¼. † Assumed to be equivalent to protein multiplied by 4⅓.

TABLE 8.

Carbon balance and estimated gain and loss of fats in respiration experiments.

The figures of column E are obtained by subtracting those in B from those in A. In like manner F = A − (B + C + D) or F = E − (C + D).

DATE.	CARBON.								Estimated Gain (+) or Loss (−) of Fat.
	A	B	C	D	E	F	G	H	
	Total Income Food.	Total Outgo in Feces.	Total Outgo in Urine.	Total Outgo in CO_2.	Total Digested.	Gained (+) or Lost (−).	In Protein. Stored (+) or Lost (−).	In Fat. Stored (+) or Lost (−).	
Experiment No. 1. *(E. O.)*	Grams.	Grms.	Grms.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Feb. 17–18, -	289.3	9.0	11.7	216.5	280.3	+52.1	+5.3	+46.8	+61.2
Feb. 18–19, -	289.3	9.0	11.0	211.7	280.3	+58.6	+9.3	+48.3	+63.1
Feb. 19 (¼ day),	111.0	3.0	2.2	49.5	108.0	+56.3	+19.9	+36.4	+47.6
Total, 2¼ days,	689.6	21.0	24.9	477.7	668.6	+167.0	+34.5	+131.5	+171.9
Experiment No. 2. *(E. O.)*									
Feb. 26–27, -	260.6	9.9	14.7	233.5	250.7	+2.5	−3.3	+5.8	+7.6
Feb. 27–28, -	260.6	9.9	13.9	207.3	250.7	+29.5	+.3	+29.2	+38.2
Feb. 28 (¼ day),	67.1	3.3	2.9	46.8	63.8	+14.1	+1.3	+12.8	+16.7
Total, 2¼ days,	588.3	23.1	31.5	487.6	565.2	+46.1	−1.7	+47.8	+62.5
Experiment No. 3. *(O. F. T.)*									
Mch. 16–17, -	239.5	6.9	8.7	220.9	232.6	+3.0	+8.3	−5.3	−6.9
Mch. 17–18, -	239.5	6.9	9.9	215.3	232.6	+7.4	+5.6	+1.8	+2.4
Mch. 18–19, -	239.5	6.9	10.6	218.8	232.6	+3.2	+5.3	−2.1	−2.7
Mch. 19–20, -	239.5	6.9	11.8	222.9	232.6	−2.1	+5.0	−7.1	−9.3
Mch. 20–21, -	239.5	6.9	13.6	221.7	232.6	−2.7	0.0	−2.7	−3.5
Total, 5 days,	1197.5	34.5	54.6	1099.6	1163.0	+8.8	+24.2	−15.4	−20.0
Experiment No. 4. *(A. W. S.)*									
Mch. 23 (⅝ day),	86.4	6.6	5.9	139.2	79.8	−65.3	−16.6	−48.7	−63.7
Mch. 24–25, -	244.1	10.5	7.6	237.0	233.6	−11.0	+2.3	−13.3	−17.4
Mch. 25–26, -	244.1	10.5	5.9	244.3	233.6	−16.6	+5.6	−22.2	−29.0
Mch. 26–27, -	244.1	10.5	8.9	231.5	233.6	−6.8	+3.6	−10.4	−13.6
Mch. 27–28, -	244.1	10.5	11.5	220.7	233.6	+1.4	+7.3	−5.9	−7.7
Mch. 28–29, -	244.1	10.5	13.0	240.6	233.6	−20.0	+9.6	−29.6	−38.7
Mch. 29–30, -	244.1	10.5	8.4	229.4	233.6	−4.2	+8.0	−12.2	−16.0
Mch. 30–31, -	244.1	10.5	10.8	243.2	233.6	−20.4	+5.6	−26.0	−34.0
Mch. 31–Apr. 1,	244.1	10.5	8.7	348.0	233.6	−123.1	+10.3	−133.4	−174.4
Apr. 1–2, - -	244.1	10.5	11.0	384.7	233.6	−162.1	−5.3	−156.8	−205.0
Apr. 2–3, - -	244.1	10.5	10.4	381.7	233.6	−158.5	+1.6	−160.1	−209.3
Apr. 3–4, - -	244.1	10.5	11.2	242.7	233.6	−20.3	−4.3	−16.0	−20.9
Apr. 4 (⅜ day,)	157.7	3.9	6.0	93.9	153.8	+53.9	+17.9	+36.0	+47.1
Total, 12 days,	2929.2	126.0	119.3	3236.9	2803.2	−553.0	+45.6	−598.6	−782.6

The methods for calculating the results from the observed data, which were found by weighings, measurements, and analyses—and are quite extensive—are explained in the publication just referred to. The estimates of income and outgo and gain or loss of protein are made by multiplying the nitrogen by the factor 6.25. The corresponding estimates for fats are made by assuming the protein to contain 53 per cent. and the fats, 76.5 per cent. of carbon. The carbon in the protein gained by the body is added to, or that in the protein lost is subtracted from, the carbon of the outgo; the resulting amount is subtracted from the total carbon of the income, and the difference, divided by .765, is taken as representing the gain or loss of fat. The estimates of potential energy are based upon direct determinations of the heats of combustion of food, feces and urine. In the estimates in which fat gained or lost by the body are involved, however, each gram of fat is assumed to contain 9.4 calories of potential energy. In the corresponding estimates of fuel value of the protein gained or lost it is assumed that incompletely oxidized nitrogenous compounds excreted in the urine will have the fuel value of the urea corresponding to the nitrogen of the protein.

DISCUSSION OF RESULTS.

VENTILATION AND PRODUCTION OF CARBON DIOXIDE.

The observations regarding ventilation and the effects of the presence of carbonic acid in large quantities are of decided interest.

The results are epitomized in table 9, from which it will be seen that the quantity of CO_2 in the incoming air, which was ordinary, fresh air from the outside of the building, was normal, ranging from .55 to .60 milligrams per liter. The ventilation in experiments 1 and 2, taken collectively, was at the rate of about 50 liters of air per minute; the CO_2 in the outgoing air varied from 8.0 to 12.7, and averaged 10.7 milligrams per liter. In experiment No. 3, with an average ventilation of 75 liters of air per minute, the range of CO_2 in the air was from 4.6 to 9.9 mg. per liter and the average 7.4 mg. per liter. The smaller quantity of CO_2 in the air as compared with experiments 1 and 2 was due to the larger ventilation, since the average weight of CO_2 given off in 24 hours was 806.4 grams

as compared to 778.6 grams in experiment 1 and 794.6 in experiment 2. In these three experiments the subject was either at rest or engaged in light mental work as reading.

TABLE 9.

Ventilation and CO_2 exhalation in four respiration experiments. Quantities of air supplied in the ventilating current and of carbon dioxide exhaled.

The CO_2 in the incoming air ranged from .55 to .60 milligrams per liter.

Rsp. Ex. No.	Subjects and Experimental Periods.	Ventilation. Air per Minute.	CO_2 in Outgoing Air. Amounts per Liter. Min.	Max.	Avg.	Avg. Wt. CO_2 given off in 24 hours.
		Liters.	Mgms.	Mgms.	Mgms.	Grams.
1	E. O., at rest, 2¼ days, - - -	49	8.0	12.5	11.0	778.6
2	E. O., at rest, 2¼ days, - - -	50	8.1	12.7	10.4	794.6
3	O. F. T., at light mental work, 5 days,	75	4.6	9.9	7.4	806.4
4	A. W. S. 1st period, at rest, 1⅝ days, -	55	8.1	12.8	10.3	848.9
	2d period, at mental work, 3 days,	55	8.7	12.8	10.5	851.5
	3d period, at rest, 3 days, - -	55	9.0	12.5	10.9	871.4
	4th period, at muscular w'k, 3 days,	55	9.9	24.6	16.8	1362.3
	5th period, at rest, 1⅜ days, -	55	10.9	13.4	11.7	897.7
	Total, 12 days, - - -	55	8.1	24.6	12.3	989.2

Experiment No. 4 is of much more interest in this connection, since the differences in mental and physical exercise were much wider. During the first and fifth periods of 1⅝ and 1⅜ days, respectively, the subject was at rest. During the second period, which lasted 3 days, he was engaged in rather severe mental work. The third period was one of as nearly absolute rest as was practicable; in the fourth the subject was engaged in severe muscular work for 8 hours per day. The rate of ventilation was 55 liters per minute. The temperature of the air in the chamber was generally from 19°–20° centigrade, though it fell at times to 17° and rose during the periods of hard muscular work to 22°.

The weight of CO_2 given off in twenty-four hours ranged from about 850 to 900 grams for the days at rest, and was no larger with mental work, but averaged over 1,360 grams for the days of muscular work. During two periods of six hours each of hard muscular work the elimination of CO_2 reached 513 and 501 grams respectively. During the night or sleeping period the exhalation of CO_2 was singularly constant irrespective of the day's occupation. It amounted to 175 grams in six hours, with but slight variation from that figure.

The weight of CO_2 in outgoing air during the periods of rest and mental work ranged from 8.1–13.4 mg. per liter, but averaged not far from 11 mg. per liter. During the period of muscular work, however, the range was from 9.9 mg. per liter in the hours of rest, *e. g.*, at night, to 24.6 mg. per liter in the hours of severe work.

Authorities on ventilation commonly estimate the maximum of carbon dioxide permissible in the air of inhabited rooms at one part per thousand by volume, which corresponds to 1 cc. or about 1.97 mg. CO_2 per liter. It will be observed that the amounts of CO_2 in the air in the respiration chamber during these experiments was from 8–25 mg. per liter, and averaged 10–12 mg. per liter. In other words, the subjects of these experiments lived constantly in an atmosphere containing from five to six times the amount of CO_2 in the standard just referred to. In experiment No. 4 the CO_2 rose to nearly thirteen times the amount in the standard. The interesting fact in this connection is that no one of the subjects appeared to experience any inconvenience whatever from either this large amount of carbon dioxide or from any other products of exhalation. In experiment No. 2 the subject was for a time somewhat ill, but, apparently, the reason for this was entirely separate from the ventilation.

The subject who remained in the apparatus during the five days of the third experiment was as comfortable in every way, according to his repeated statements both during the experiment and afterwards, as if he had been breathing the air of an ordinary well-ventilated room. Even in the fourth experiment the subject was not aware of the least inconvenience or sense of discomfort during the twelve days of his sojourn in the chamber.

It may be added that these results are in accord with the late experiments by Messrs. Billings, Mitchell, and Bergey,* which imply that the discomfort experienced in poorly ventilated rooms is not due to the excess of carbon dioxide.

We venture the suggestion, however, that one cause of the discomfort felt in ill-ventilated rooms occupied by a number of

* The Composition of Expired Air and its Effects upon Animal Life. By J. S. Billings, M. D.; S. Weir Mitchell, M. D.; and D. H. Bergey, M. D. City of Washington. Published by the Smithsonian Institution, 1895. From Smithsonian Contributions to Knowledge, vol. xxix. (No. 989. Hodgkins Fund.)

people may be the large amount of moisture which accumulates in the air while at the same time the temperature rises. Some of the observations made in the experiments above described accord with this hypothesis.

NUTRIENTS AND ENERGY.

The nutrients and potential energy of the food eaten and of that digested in the four experiments are summarized in tables 10 and 12. Table 11 shows the balance of nitrogen and of carbon.

In the first experiment the diet was high in protein. The subject, a laboratory janitor, was accustomed to somewhat active muscular work and had a very hearty appetite. The diet was of his own selection and proved more than sufficient for the needs of his organism during the experiment when he was comparatively inactive. His organism stored both protein and fat.

In the next experiment, which was made with the same person, the diet was the same in kind but less in quantity. The ration proved insufficient to maintain the nitrogen equilibrium, although some fat was stored. In this case, however, the quantity of protein lost and of fat gained were quite small, so that the organism was very nearly in equilibrium, especially as regards nitrogen.

TABLE 10.

Nutrients in the four respiration experiments. Total and digestible nutrients in daily food with corresponding potential energy and average daily gain or loss of body protein and fat.

Resp. Expt. No.	Subject and Length of Experiment.	Nutrients and Energy in Daily Food.								Gain (+) or Loss (—) in Body per Day.	
		Total.				Digested.					
		Protein.	Fat.	Carbo-hydrates.	Potential Energy Determined.	Protein.	Fat.	Carbo-hydrates.	Potential Energy Determined.	Protein.	Fat.
		Gr.	Gr.	Gr.	Cal.	Gr.	Gr.	Gr.	Cal.	Gr.	Gr.
1	E. O., 2¼ days, -	143	126	296	3230	136	123	290	2960	+14	+62
2	E. O., 2¼ days, -	121	112	281	2925	110	109	277	2645	— 3	+23
3	O. F. T., 5 days,	103	78	338	2725	95	74	331	2530	+ 9	— 4
4	A. W. S., 12 days,	101	65	329	2740	93	82	321	2500	+ 8	—66

TABLE 11.

Nitrogen and carbon balance in four respiration experiments. Average daily income and outgo and gain or loss of nitrogen and carbon in the body.

Resp. Ex. No.	Subjects and Experimental Periods.	In Digested Nutrients of Food.		In Material Consumed in the Body.		Gain (+) or Loss (—) in the Body.	
		N.	C.	N.[1]	C.[2]	N.	C.
		Gr.	Gr.	Gr.	Gr.	Gr.	Gr.
1	E. O., 2¼ days, no work, - -	21.8	280.3	19.6	225.5	+2.2	+ 54.8
2	E. O., 2¼ days, no work, - -	17.6	250.7	18.0	234.7	—0.4	+ 16.0
3	O. F. T., 5 days, light mental work,	15.2	232.6	13.7	230.9	+1.5	+ 1.7
4	A. W. S.: 1st period, rest, 1⅝ days, -	14.8	233.6	14.1	238.5	+0.6	— 4.9
	2d period, mental work, 3 days,	14.8	233.6	13.1	241.0	+1.7	— 7.4
	3d period, rest, 3 days, - -	14.8	233.6	12.5	248.4	+2.3	— 14.8
	4th period, muscular w'k, 3 days,	14.8	233.6	14.1	381.5	+0.7	—147.9
	5th period, rest, 1⅜ days, -	14.8	233.6	15.2	260.2	—0.4	— 26.6
	Whole experiment, 12 days,	14.8	233.6	13.6	279.7	+1.2	— 46.1

[1] Total nitrogen of urine.

[2] Carbon of CO_2 exhaled plus that of urine.

TABLE 12.

Protein and energy in four respiration experiments. Comparison of protein and potential energy of the digested nutrients of the food with the protein and potential energy of the materials consumed and of the materials gained and lost in the body. Average quantities per day.

Resp. Ex. No.	Subjects and Experimental Periods.	In Digestible Nutrients of Food.		In Material Consumed in the Body.		In Material Gained (+) or Lost (—) in the Body.	
		Protein.	Energy.	Protein.	Energy.	Protein.	Energy.
		Gr.	Cal.	Gr.	Cal.	Gr.	Cal.
1	E. O., 2¼ days, no work, - -	136	2960	122	2310	+14	+ 650
2	E. O., 2¼ days, no work, - -	110	2645	113	2440	— 3	+ 205
3	O. F. T., 5 days, light mental work,	95	2530	86	2530	+ 9	0
4	A. W. S.: 1st period, rest, 1⅝ days, -	93	2520	89	2585	+ 4	— 65
	2d period, mental work, 3 days,	93	2510	82	2615	+11	— 105
	3d period, rest, 3 days, - -	93	2485	78	2695	+15	— 210
	4th period, muscular w'k, 3 days,	93	2500	88	4325	+ 5	—1825
	5th period, rest, 1⅜ days, -	93	2520	95	2840	— 2	— 320
	Whole experiment, 12 days,	93	2500	85	3080	+ 8	— 580

In the third experiment the diet was considerably smaller in protein and energy than in the two preceding. The subject, a chemist, was accustomed to rather less muscular labor than the person in the first experiment. He was also rather lighter in weight and the diet which he chose was smaller in both nutrients and energy. There was a slight gain of protein and loss of fat during the experiment, but on the whole the organism was very nearly in equilibrium in respect to both nitrogen and carbon. The fuel value of the material actually consumed in the body was larger than either of the two preceding experiments, though somewhat smaller than that in the fourth experiment under similar conditions.

In the fourth experiment the subject was a physicist. He was taller than the subject of the third and heavier than either of the subjects in the preceding experiments. The diet, which was of his own selection, as in the previous cases, was the smallest of all in protein, though it was very nearly the same in energy as that of the third experiment. Nevertheless, the figures indicate a slight gain rather than loss of protein during all of the periods of the experiment when there was no especially large muscular activity, though there was constant loss of fat from the organism. In the period of muscular activity the loss of fat was very much larger, and there was apparently a slight loss rather than gain of protein in the organism as shown in tables 13 and 14, where allowance is made for a lag of 30 hours in the urine. The loss of carbon during the hard muscular work amounted to 148 grams per day.

It has been stated above (p. 102), that in experiment No. 4 six hours was allowed for the lag of the urine. That this time was insufficient was also pointed out, and 30 hours was suggested as the more probable period of lag. Tables 13 and 14 give the nitrogen and carbon balance in this experiment, together with the calculated protein and energy, allowing for both 6 hours' lag and 30 hours' lag. It will be seen that the results are much more uniform under the latter supposition than under the former. Thus when we allow 6 hours' lag the protein consumed during the three periods of mental work, rest, and muscular work are 82, 78, and 88 grams per day, respectively, while with a 30 hours' lag the corresponding values would be 79, 78, and 98 grams.

Table 13 shows the average daily income and outgo and gain or loss for each period. The estimates for nitrogen are on the basis of six hours and of thirty hours' lag in urine.

Table 14 shows comparison of protein and potential energy of the digested nutrients of the food with the protein and energy of the materials consumed and of the materials gained or lost from the body. The average quantities are those per day for each period. The estimates for nitrogen are on the basis of six hours' and of thirty hours' lag in the urine.

TABLE 13.

Nitrogen and carbon balance in experiment No. 4.

PERIODS OF THREE DAYS EACH.	IN DIGESTED NUTRIENTS OF FOOD.		IN MATERIAL CONSUMED IN THE BODY.		GAIN (+) OR LOSS (−) IN THE BODY.	
	N.	C.	N.	C.	N.	C.
	Grams	Grams.	Grams	Grams.	Grams.	Grams.
Allowing 6 hours' lag.						
Hard mental work, - -	14.8	233.6	13.1	241.0	+1.7	— 7.4
Rest, - - - - - -	14.8	233.6	12.5	248.4	+2.3	— 14.8
Hard muscular work, - -	14.8	233.6	14.1	381.5	+ .7	—147.9
Allowing 30 hours' lag.						
Hard mental work, - -	14.8	233.6	12.7	241.0	+2.1	— 7.4
Rest, - - - - - -	14.8	233.6	12.4	248.4	+2.4	— 14.8
Hard muscular work, - -	14.8	233.6	15.6	381.5	— .8	—147.9

TABLE 14.

Balance of protein and energy in experiment No. 4.

PERIODS OF THREE DAYS.	IN DIGESTED NUTRIENTS OF FOOD.		IN MATERIAL CONSUMED IN THE BODY.		GAIN (+) OR LOSS (−) IN THE BODY.	
	Protein.	Energy.	Protein.	Energy.	Protein.	Energy.
	Gr.	Cal.	Gr.	Cal.	Gr.	Cal.
Allowing 6 hours' lag.						
Hard mental work, - -	93	2510	82	2615	+11	— 105
Rest, - - - - - -	93	2485	78	2695	+15	— 210
Hard muscular work, - -	93	2500	88	4325	+ 5	—1825
Allowing 30 hours' lag.						
Hard mental work, - -	93	2480	79	2595	+14	— 115
Rest, - - - - - -	93	2505	78	2715	+15	— 210
Hard muscular work, - -	93	2515	98	4325	— 5	—1810

THE MATERIALS AND ENERGY ACTUALLY CONSUMED AND THOSE GAINED OR LOST BY THE BODY.

In the discussion and tables above, the distinction has been made between the quantities of nutrients in the total food, those in the food digested and those actually consumed. Where the organism is in equilibrium, and there is neither gain nor loss of material, the quantities digested and those consumed would be the same. When, however, there is a gain of protein or fat the quantity consumed is less than that digested. On the other hand a loss of protein or fat corresponds to a consumption in excess of the amounts digested from the food. The tables give the quantities of energy corresponding to the nutrients consumed, as well as those eaten and digested. From these data tables 15 and 16 are drawn up with the purpose of indicating more clearly the comparison of protein and energy in the nutrients digested and in the material actually consumed in the body, together with a gain or loss of protein and energy. It is interesting to note the differences in the different experiments with the three persons who were the subjects. The differences in the persons as to weight, ordinary occupation and diet have been already referred to. It will, however, be of interest to add that some studies had been previously made which throw a little more light upon the dietary habits of two of them.

Two dietary studies were made in the family of the laboratory janitor, one in November and the other in March.* In these the average protein in the food eaten per man per day was estimated at 126 grams, and the total energy of the nutrients at 3,900 calories. The corresponding amounts digested were estimated at approximately 116 grams of protein and 3,660 calories. This was, on the whole, a liberal diet. It is slightly larger than the standard tentatively proposed by Prof. Atwater for an ordinary man at moderately hard muscular work.

Two dietary studies were made by the subject of experiment 4 at his home in a country town in another State on the occasion of vacation visits, one in the winter and the other in summer.† There was but little difference between the results of the two, and it may be supposed that they represent the dietary habits which this gentleman had naturally acquired. The averages per man per day were, approximately, for the

* Page 117, beyond; dietaries Nos. 15 and 19. † *Ibid*, Nos. 27 and 174.

total food eaten, 79 grams of protein and 3,125 calories of energy. These quantities are estimated to correspond to about 71 grams of protein and 2,955 calories of energy in the food actually digested.

These observations, taken in connection with the differences of occupation, are of interest in comparison with the figures of the tables above. In tables 15 and 16 the results are put together in such form as to bring out more clearly the comparisons between the quantities of nutrients and energy in the food, the quantities actually consumed by the body, and the gain or loss by the body in each case. The figures for experiment 4 are computed on the basis of 30 hours' lag in the urine.

It will be observed that the laboratory janitor, who was accustomed to moderately active muscular work, ten hours per day, and who was what would be called a "hearty eater," consumed during the first experiment 122 grams of the 136 grams of digestible protein in his food, and at the same time stored the remaining 14 grams according to the calculations of these experiments. Of the 2,960 calories in the food digested he consumed material corresponding to 2,310 calories. The digested nutrients of the food furnished an excess of carbohydrates and fats as well as protein, so that his organism stored fat and protein corresponding to 650 calories of energy. In the second experiment his diet was reduced so as to supply only 110 grams of digestible protein and 2,645 calories of energy. In this case his organism was estimated to consume 113 grams of protein, a trifle more than the food supplied, and 2,440 calories of energy. The organism gained considerable fat, enough to make a gain of material corresponding to 205 calories of energy.

The subjects of experiments 3 and 4, who were accustomed to only light muscular activity as is natural with their professional work, chose for their diet materials computed to supply 95 and 93 grams of digestible protein and other digestible nutrients sufficient to furnish about 2,500 calories of energy per day. When at rest in the respiration apparatus or engaged in either light or severe mental work, they consumed from 79 to 86 grams of protein and from about 2,500 to 2,700 calories of energy. This consumption must have been reasonably economical, since the amounts of nutrients available were so small.

TABLE 15.

Recapitulation of amounts of protein and energy consumed daily in each of the four respiration experiments.

Resp. Expt. No.	Subjects and Occupation.	Number of Days.	In Digested Nutrients of Food. Protein.	In Digested Nutrients of Food. Energy.	In Materials Consumed in the Body. Protein.	In Materials Consumed in the Body. Energy.	Gain (+) or Loss (—) in the Body. Protein.	Gain (+) or Loss (—) in the Body. Energy.
			Gr.	Cal.	Gr.	Cal.	Gr.	Cal.
	E. O., laboratory janitor. Weight, 148 lbs. Accustomed to moderately active exercise, and to liberal diet with considerable protein.							
1	1st experiment, larger ration,	2¼	136	2960	122	2310	+14	+ 650
2	2d experiment, smaller ration,	2¼	110	2645	113	2440	— 3	+ 205
3	O. F. T., chemist. Weight, 140 lbs. Accustomed to light muscular activity and moderate diet.	5	95	2530	86	2530	+ 9	0
4	A. W. S., physicist. Weight, 168 lbs. Accustomed to light muscular activity, and to diet with relatively small proportion of protein.							
	Severe mental work, - -	3	93	2480	79	2595	+14	— 115
	Absolute rest, - - -	3	93	2505	78	2715	+15	— 210
	Severe muscular work, - -	3	93	2515	98	4325	— 5	—1810
	Whole experiment, - -	12	93	2500	85	3080	+ 8	— 580

TABLE 16.

Comparison of materials and energy of digested food with those gained and lost by the body.

Resp. Expt. No.	Subjects and Occupation.	Number of Days.	In Digestible Nutrients of Daily Food. Protein.	Fat.	Carbohydrates.	Energy.	Gain (+) or Loss (—) in Body per Day. Protein.	Fat.	Energy.
			Gr.	Gr.	Gr.	Cal.	Gr.	Gr.	Cal.
1	E. O., no work, - -	2¼	136	123	290	2960	+14	+ 62	+ 650
2	E. O., no work, - -	2¼	110	109	277	2645	— 3	+ 23	+ 205
3	O. F. T., light mental work,	5	95	74	331	2530	+ 9	— 4	0
4	A. W. S. 1st period, rest, - -	1⅝	93	82	321	2500	+ 4	— 9	— 65
	2d period, mental work,	3	93	82	321	2500	+11	— 17	— 105
	3d period, absolute rest,	3	93	82	321	2500	+15	— 30	— 210
	4th period, muscular w'k,	3	93	82	321	2500	+ 5	—196	—1825
	5th period, rest, - -	1⅜	93	82	321	2500	— 2	— 33	— 320
	Whole experiment, -	12	93	82	321	2500	+ 8	— 66	— 580

The food in experiment 3 supplied only a trifle more protein and no more energy than was consumed, while in experiment 4, when the subject was at rest or engaged in mental work, there was, with a slight, apparent gain of protein, a decided loss of fat. That the subject of experiment 4, although a man of larger frame and larger weight than the one of experiment 3, consumed less protein, seems to accord with his habit of using small quantities of protein which is implied in the dietary studies mentioned above. But while his organism consumed smaller quantities of protein it consumed more fat and more energy than was the case with the subject of experiment 3. When the same person engaged in severe muscular work the consumption of protein rose from 78 to 98 grams per day. The consumption of energy at the same time rose from 2,715 to 4,325 calories. That there should be such an increase in the consumption of both protein and energy with the severe muscular work is not at all surprising. How the consumption of protein during the period of muscular work would have been affected if the quantity of carbohydrates and fats had been sufficient, is of course uncertain.

IN CONCLUSION.

The experiments above described offer considerable material for discussion. Since, however, they are of a preliminary character, and are to be followed by others in which the results of the experience here obtained will be used, it is deemed best to reserve the discussion until at least some of the anticipated work shall have been accomplished. Meanwhile the following statements are perhaps in place:

1. The experience here obtained emphasizes the desirability of longer experimental periods than have been customary in experiments of this class. Although a considerable number of respiration experiments have been made elsewhere with animals and man, the periods have rarely exceeded 24 hours. The results here obtained are sufficient to show that the results obtained in periods so short are less conclusive than is to be desired.

2. Much care needs to be bestowed upon the analyses of the materials of income and outgo. In the majority of experiments elsewhere reported the composition of food and solid and liquid excretory products has been in large part assumed rather than estimated from direct analyses of specimens of the

materials belonging to the experiments. In like manner there is need of the greatest possible care and accuracy in the determination of the gaseous excretory products. Nor can any of the organic matters given off in perspiration and exhalation be left out of account if the fullest accuracy is to be attained.

3. It is to be hoped that future experience may lead to such improvements as shall insure the accurate measurement of all the chemical elements involved in the income and outgo. It is evident that there are no insurmountable obstacles in the way of reasonably accurate estimation of the income and outgo of nitrogen and carbon. As regards the hydrogen the difficulties of determination have thus far been more serious, but they do not appear to be by any means insurmountable. The quantities of sulphur and phosphorus are so small that extreme accuracy is needed for their estimation in order to insure satisfactory comparison of income and outgo. The experience in this laboratory leads us, however, to hope that by refinement of methods and care in manipulation reasonably reliable results may be obtained.

4. The prospects for obtaining a satisfactory balance of income and outgo of energy are on the whole decidedly encouraging. The determination of heats of combustion by the bomb calorimeter are eminently satisfactory and there seems to be good ground to hope that ultimately the measurements of heat given off from the body may also prove feasible within the limits needed for such purposes. Satisfactory results have already been reported by other experimenters with small animals, and indeed with men during experiments of short duration.

5. The results of these experiments and of similar investigations elsewhere bring out very clearly the differences in the amounts of nutrients and energy required by the organisms of different persons under different conditions. A large amount of work will be needed, however, to bring the experimental data necessary for accurate generalizations. The importance of the subject is such as to call for the most extensive and painstaking research. We may confidently expect that with the growth of inquiry, which has of late become so rapid in Europe, and may be anticipated in the United States, the needed information will gradually accumulate.

STUDIES OF DIETARIES.

REPORTED BY W. O. ATWATER AND A. P. BRYANT.

Accounts of studies of dietaries of families, boarding houses, and clubs made by the Station have been given in previous reports as follows:

1. A boarding house. (1)
2. A chemist's family. (1)
3. A jeweler's family. (2)
4. A blacksmith's family. (2)
5. A machinist's family. (2)
6. A mason's family. (2)
7. A carpenter's family. (2)
8. A carpenter's family. (2)
9. The family of the Station Agriculturist in winter. (3)
10. A mason's family (the same as No. 6). (3)
11. A carpenter's family (the same as No. 8). (3)
12. A College students' club. (3)
13. The family of the Station Agriculturist in summer. (3)
14. A widow's family. (4)
15. A Swedish laborer's family. (4)
16. A College club. (4)
17. A Divinity School club. (4)
18. A College lady students' club. (4)
19. A Swedish laborer's family (same as No. 15). (4)
20. Three chemists. (4)
21. A carpenter's family. (4)
25. An infant nine months old. (5)
26. A chemist's family. (5)
27. A farmer's family. (5)
28. A chemist's family (same as No. 26). (5)
29. A chemist's family (same as No. 26). (5)
45. A farmer's family. (5)
46. A farmer's family (same as No. 45). (5)
120. A farmer's family. (5)
121. A farmer's family. (5)
123. A farmer's family. (5)
124. A College students' eating club. (5)

Nine additional studies are here reported:

23. A family in Hartford.
24. A laborer's family in Hartford.
156. A farmer's family (same as No. 120).
157. A farmer's family (same as No. 121).
164. The family of the Station Agriculturist.
173. A private boarding house.
174. A farmer's family (same as No. 27).
175. A man in the Adirondacks under treatment for consumption.
176. A camping party in Maine.

Dietary studies 23 and 24 were conducted in Hartford by Miss Helen M. Hall, under the joint auspices of the Hartford School of Sociology and the Station. Nos. 156 and 157 were

(1) Report of this Station, 1891, pp. 90–106. (2) *Ibid*, 1892, pp. 135–162. (3) *Ibid*, 1893, p. 174–197. (4) *Ibid*, 1894, pp. 174–204. (5) *Ibid*, 1895, pp. 129–174.

made by Prof. J. L. Bridge, who was at the time connected with the Connecticut Literary Institute, Suffield. They were, like Nos. 45, 46, 120, and 121, conducted by the Station in coöperation with the U. S. Department of Agriculture. No. 164 was made by Prof. C. S. Phelps at Storrs. No. 173 was made by Dr. Almah J. Frisby, who was at the time studying in the chemical laboratory of Wesleyan University. No. 174 was, like No. 27, conducted by Mr. A. W. Smith in Vermont. The data for No. 75 were kindly furnished by the subject, who made the study of his own dietary. Those of No. 176 are due to the courtesy of a member of the party.

The analyses, where such seemed called for and feasible, were made mostly by Mr. H. M. Burr.

PURPOSE OF THE INVESTIGATIONS.

The purpose of these investigations is to accumulate definite information regarding the practice of people of different classes, and in different places, in respect to the purchase and use of their food. Such information, coupled with that which comes from the study of the composition, digestibility, and nutritive value of our common food materials on the one hand, and on the other with that which comes from research into the laws of nutrition, including such as is illustrated by the metabolism experiments reported in the previous pages, will gradually make it possible to judge as to what are the more common dietary errors and how improvements may be made to the advantage of health, purse, and home life. To this end, however, much painstaking research will be necessary. It is very fortunate that a considerable number of experiment stations, colleges, and other organizations, as well as private individuals, in different parts of the country, are coöperating in such inquiries under the leadership of the U. S. Department of Agriculture, so that the much needed knowledge is accumulating much more rapidly than would otherwise be possible.

PLAN OF THE INVESTIGATIONS.

The general plan of the investigations includes the determination of the amounts and nutritive value of the food consumed by a given number of persons during a certain number of days, and the deducing of the quantities per man per day.

In the study of the dietary of a family, boarding house, or boarding club, account is taken of the amounts, composition, and cost of all food materials of nutritive value in the house at the beginning, purchased during, and remaining at the end of the experiment, and of all the kitchen and table wastes. The accessories, as baking powder, essences, salt, condiments, tea, coffee, etc., though of interest from a pecuniary standpoint, are of practically no value as regards nutriments. The amounts of different food materials on hand at the beginning and received during the experiment are added; from this sum the amounts remaining at the end are subtracted. This gives the amount of each material actually used. From the amount thus obtained and the composition of each material, as shown by analysis, the amounts of the nutritive ingredients are estimated. From these are subtracted the amounts of nutrients in the waste, and thus the amounts of the nutrients actually eaten are learned. Account is kept of the meals taken by the different members of the family, and by visitors. The number of meals for one man, to which the total number of actual meals taken is equivalent, is estimated upon the basis of the potential energy, as has been done in previous investigations here. These energy equivalents, which are stated below, are somewhat arbitrary, and will require revision in the light of accumulating inquiry.

Estimated relative quantities of potential energy in nutrients required by persons of different classes.

Man at moderate work,	1.0
Woman at moderate work,	.8
Boy between 14 and 16, inclusive,	.8
Girl between 14 and 16, inclusive,	.7
Child between 10 and 13, inclusive,	.6
Child between 6 and 9, inclusive,	.5
Child between 2 and 5, inclusive,	.4
Child under 2,	.3

Two of the studies, Nos. 175 and 176, were somewhat exceptional, as is explained in the special descriptions of the individual studies beyond.

In each study the data regarding the kinds and amounts of food materials, the persons by whom they were eaten, and the number of days and meals, were sent to the Station at Middletown, where the necessary computations were made. The

analyses were made from specimens of the food materials collected with the statistical data of the studies, and sent with them to the Station. The computations have been under the supervision of Mr. A. P. Bryant.

EXPLANATION OF TABLES.

The following statements and tables contain the main results of the inquiries, including all the data used in the computations. In order to reduce the bulk of the statistics, however, some of the details given in previous reports are omitted here. The statistics of each dietary include the kinds of food materials used, with the weight and cost of each.

Composition of food materials.—The figures used for the percentages of nutrients in each food material may be found in tables 17 and 60. The reference number opposite each material is that for the corresponding material in table 17. Those marked "a" in the former table represent results of analyses of samples of the food materials actually used in the respective dietaries. The number of materials of which such special analyses were made was, however, small. For the rest of the food materials, which make up the large majority of the whole, the composition was assumed from the averages given for like food materials in Bulletin 28 of the Office of Experiment Stations of the Department of Agriculture.* The figures in that Bulletin represent the results of a compilation of analyses made previous to January 1, 1895, and were used for computing the nutrients in the dietaries published in the last (1895) as well as the present report of this Station. Table 60 beyond gives the composition of a number of food materials as revised to January 1, 1896. Some of the figures of this latter table are the same as those for 1895 in the Bulletin just named, others have been slightly altered. The materials, of which the figures for composition actually employed for the computations differ from those in table 60, are included in table 17, and are indicated by the reference numbers, which are the same as those in the lists with the several dietaries. Those materials for which the figures for composition used in the computations are the same as in table 60 are indicated in the lists by the letter "M" in the column of reference numbers.

* On the Composition of American Food Materials, by W. O. Atwater and C. D. Woods.

Details of individual dietaries.—In the introductory statement for each dietary the number of meals for one man equivalent to those actually eaten are computed by use of the figures for relative amounts of potential energy in nutrients as above explained. In dietary No. 23, for instance, the man had 42 meals during the whole period of two weeks. The three women had together 105 meals. Assuming that a woman eats 0.8 as much as a man, these 105 meals of women would be equivalent to 84 meals for a man. In like manner the 42 meals for the child are estimated as equivalent to 17 meals for a man. The sum, 143 meals for a man, would be equivalent to three meals per day for 48 days.

The first table for each dietary shows the actual weights and costs of the different food materials for the whole period of the study in each case.

The second table in each dietary shows the weights of the food materials, the weights of the nutritive ingredients, and the costs, as calculated for one man for ten days. It shows also the percentages which the different kinds of food and the nutrients contained in it make of the total food and the total nutrients.

For the sake of simplicity and convenience, the computed quantities for one man for ten days are given, instead of the actual quantities consumed, or the quantities for one man for one day. If the quantities were stated as actually consumed in the period of each dietary, it would not be easy to compare the quantities in different dietaries. By putting the quantities for all of the dietaries on one basis, however, the relative amounts of the different kinds of food materials, as meats, milk, bread and the like in the different dietaries are readily compared. If the quantities were given per man per day, some would be too small for printing without the use of an inconvenient number of decimal places. To learn the amounts per man per day it is necessary only to remove the decimal point one place to the left.

The third table in each dietary gives the nutrients and energy in the total food purchased during the actual period of the experiment, the proportions in the table and kitchen wastes, and those in the food actually eaten.

In estimating the fuel values of the nutritive ingredients, the protein and carbohydrates are assumed to contain 4.1 and

the fats 9.3 calories of potential energy per gram. These correspond to 1,860 calories for one pound of protein or carbohydrates and 4,220 calories for one pound of fats.

Waste.—The words "refuse" and "waste" are used somewhat indiscriminately. In general, refuse in animal food represents inedible material, although bone, tendon, etc., which are classed as refuse, may be utilized for soup. The refuse of vegetable foods, such as parings, seeds, etc., represent not only inedible material, but also more or less of edible material. The waste includes the edible portion of the food, as pieces of meat, bread, etc., which might be saved, but is actually thrown away with the refuse.

In the studies here described the refuse and waste were separated so far as practicable and the latter was collected, dried, and analyzed. No attempt has been made in these investigations until recently to keep the animal wastes and the vegetable wastes separate, but rough calculations have been made of the nutrients of the waste which came from the animal and of those which came from the vegetable food.* Inasmuch, however, as different families do not waste the same kinds of food in the same proportions, the plan has been adopted of separating the animal and vegetable wastes wherever practicable.

But while this latter method gives the actual amount of animal and vegetable protein and carbohydrates wasted, it does not necessarily show the relative amounts of animal and vegetable fat wasted, because of the use of animal fats such as those in suet, lard, butter, and milk, in the cooking of vegetable foods such as bread, cake, etc. It follows, therefore, that the vegetable waste may contain a considerable amount of animal fat. This was shown in an exaggerated form in dietary studies recently made at the Maine State College† where, in one instance, the fat in the vegetable waste, largely bread and pastry, was larger than the actual amount of fat in the raw material of the vegetable foods consumed. No attempt is here made to distinguish between animal and vegetable fat in the wastes.

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* See Report of this Station, 1895, pp. 131, 132.

† Bulletin No. 37, Office of Experiment Stations, U. S. Department of Agriculture.

TABLE 17.

Percentages of nutrients in food materials as used in the calculations of the following dietaries.

FOOD MATERIALS.	Ref. No.	Protein.	Fat.	Carbohydrates.
EDIBLE PORTION.[1]		%	%	%
Beef.				
Round,	1	19.7	13.5	—
Rump,	2	16.8	25.6	—
Corned,	3	15.6	25.4	—
Veal.				
Rib,	4	20.2	6.2	—
Lamb.				
Leg,	5	18.5	16.5	—
Loin,	6	17.6	28.3	—
Shoulder,	7	17.5	29.7	—
Mutton.				
Loin,	8	15.9	33.2	—
Pork.				
Bacon,	9	10.0	67.2	—
Eggs,	10	14.9	10.6	—
Carrots,	11	1.1	.4	9.2
Celery,	12	1.4	.1	3.0
Onions,	13	1.7	.4	9.9
Parsnips,	14	1.7	.6	16.1
Peas, green,	15	4.4	.5	16.1
Potatoes,	16	2.1	.1	18.0
Sweet Potatoes,	17	1.8	.7	27.1
Squash,	18	1.6	.6	10.4
Turnips,	19	1.4	.2	8.7
Apples,	20	.5	.5	16.6
Bananas,	21	1.2	.8	22.9
Grapes,	22	1.3	1.7	17.7
Prunes,	23	2.4	.8	68.9
Raisins,	24	2.5	4.7	74.7
Cherries,	25	1.1	.8	11.4
AS PURCHASED.[2]				
Beef.				
Brisket,	26	12.5	31.9	—
Round,	27	18.1	12.6	—
Round *(a)*,	28	19.8	3.7	—
Round *(a)*,	29	19.9	10.1	—
Round, 2d cut,	30	14.0	5.8	—
Rump,	31	13.2	20.2	—
Shoulder steak *(a)*,	32	18.4	12.6	—
Tripe,	33	10.9	1.2	—
Corned,	34	14.4	22.0	—
Bologna,	35	18.6	18.2	—
Veal.				
Neck,	36	13.3	4.6	—
Shoulder,	37	16.6	8.7	—

FOOD MATERIALS.	Ref. No.	Protein.	Fat.	Carbohydrates.
AS PURCHASED.[2]		%	%	%
Lamb.				
Leg,	38	15.2	13.6	—
Side,	39	14.2	18.7	—
Mutton.				
Leg,	40	14.9	14.9	—
Loin,	41	13.2	28.6	—
Loin *(a)*,	42	15.5	21.1	—
Loin *(a)*,	43	13.9	30.5	—
Neck,	44	11.7	17.6	—
Pluck,[3]	45	21.8	8.5	3.5
Pork.				
Loin *(a)*,	46	14.4	25.8	—
Bacon,	47	9.2	61.8	—
Fat, salt,	48	1.8	87.2	—
Sausage,	49	12.8	45.4	.8
Sausage *(a)*,	50	17.0	55.0	—
Poultry.				
Chicken, canned,	51	20.5	30.0	—
Fish.				
Smelts,	52	10.0	1.0	—
Salmon, canned,	53	20.7	10.8	1.2
Eggs,	54	13.1	9.5	—
Cheese,	55	26.0	34.2	2.3
Cheese, Dutch,	56	37.1	17.7	—
Cheese, Neufchatel	57	18.7	27.4	1.5
Milk *(a)*,	58	3.4	5.2	5.0
Milk *(a)*,	59	3.7	4.8	3.1
Milk,[4]	60	3.3	5.0	5.0
Skim milk *(a)*,	61	3.7	1.7	4.9
Buckwheat, prep'd,	62	7.9	1.2	74.9
Buckwheat flour,	63	6.1	1.0	77.2
Corn meal,	64	8.9	2.2	75.1
Bread flour,	65	11.3	1.1	74.6
Bread flour *(a)*,	66	13.2	1.2	75.1
Bread flour *(a)*,	67	10.1	1.3	76.8
Bread flour *(a)*,	68	13.3	.6	75.1
Pastry flour *(a)*,	69	10.4	1.0	75.6
Pastry flour *(a)*,	70	10.8	.4	76.8
Pastry flour *(a)*,	71	11.1	.3	76.4
Graham flour,	72	13.7	2.2	70.3
Crushed wheat,	73	11.9	1.7	74.5
Rolled oats,	74	16.9	7.2	66.8
Oatmeal,	75	15.6	7.3	68.0
Oatmeal *(a)*,	76	18.0	7.8	65.2
Rice,	77	7.8	.4	79.0
Mellin's food,	78	11.0	.3	80.6

TABLE 17.—*(Continued.)*

FOOD MATERIALS.	Ref. No.	Protein.	Fat.	Carbo-hydrates.	FOOD MATERIALS.	Ref. No.	Protein.	Fat.	Carbo-hydrates.
AS PURCHASED.		%	%	%	AS PURCHASED.		%	%	%
Rye meal, - -	79	7.1	.9	78.5	Spinach, - -	104	2.1	.5	3.1
Macaroni, - -	80	11.7	1.6	72.9	Turnips, - -	105	1.0	.1	6.1
Bread, white, -	81	9.5	1.2	52.8	Tomatoes, canned,	106	1.2	.2	4.0
Bread, graham, -	82	8.5	1.8	55.9	Apples, - -	107	.4	.4	12.4
Crackers, milk, -	83	9.3	13.1	69.2	Apples, dried, -	108	1.4	3.0	57.6
Crackers, soda, -	84	10.3	9.4	70.5	Bananas, - -	109	.7	.5	13.7
Crackers, pilot bread	85	12.4	4.4	74.2	Blackberries, -	110	.8	2.1	56.4
Cake, - - -	86	7.0	8.1	63.4	Crab apples, canned	111	.3	2.4	34.4
Cake, fruit, - -	87	6.6	10.5	64.7	Currants, dried, -	112	1.2	3.0	65.7
Cake, chocolate, -	88	5.7	9.4	66.1	Jelly, - - -	113	1.1	—	77.1
Ginger bread, -	89	5.4	9.5	64.7	Pineapples, canned,	114	.4	.7	36.4
Sugar cookies, -	90	6.8	8.9	75.3	Oranges, - -	115	.6	.4	7.1
Doughnuts, - -	91	6.6	21.9	52.6	Prunes, dried, -	116	2.0	.7	58.6
Mince pie, - -	92	6.5	12.1	37.2	Raspberries, -	117	1.0	—	12.6
Molasses, - -	93	2.7	—	68.0	Cocoanut, shredded	118	6.3	57.4	31.5
Honey, - -	94	—	—	75.0					
Corn starch, -	95	—	—	98.0					
Chocolate, - -	96	12.5	47.1	26.8	Waste *(a)*, - -	119	20.3	29.0	46.2
					Waste *(a)*, - -	120	15.5	40.4	39.9
Asparagus, - -	97	1.8	.2	3.3	Waste *(a)*, - -	121	20.4	51.1	9.0
Cabbage, - -	98	1.8	.3	4.9	Waste *(a)*, - -	122	13.1	12.9	69.6
Carrots, - -	99	.9	.3	7.4	Waste *(a)*, - -	123	19.7	36.6	35.6
Onions, - -	100	1.5	.4	8.9	Waste *(a)*, - -	124	33.0	58.0	—
Peas, dried, - -	101	24.1	1.1	61.5	Waste *(a)*, - -	125	—	100.	—
Potatoes, - -	102	1.8	.1	15.3	Waste *(a)*, - -	126	7.3	12.6	74.0
Potato chips, -	103	7.6	35.5	50.6	Accumulated fat,	127	—	95.0	—

[1] The term "edible portion" is applied to the food materials from which refuse, *i. e.*, bone of meat, shells of eggs, skins of potatoes, etc., had been removed when the weights as given in the detailed accounts of the dietaries beyond were made.

[2] The term "as purchased" indicates that the materials in this category were in the condition in which they were bought in the markets, whether they contained refuse, as the meats, or were free from refuse, as milk or bread.

[3] The "pluck" consists of parts of the heart, lungs, and liver. The composition is calculated from the probable proportion of each.

[4] The fat was estimated from the amount of milk required to make a pound of butter.

a The analyses marked "*a*" were made in connection with the dietaries in which they are used.

No. 23. DIETARY OF A FAMILY IN HARTFORD, CONN.

The study continued two weeks in the winter of 1894–95. The members of the family and number of meals taken were as follows:

Man, about 70 years old, - - - - - - -	42 meals.
Three women, between 35 and 50 years old (105 x .8), equivalent to - - - - - - - - -	84 meals.
Girl, 5 years old (42 x .4), equivalent to - - - - -	17 meals.
Total number of meals taken equivalent to - -	143 meals.

Equivalent to one man 48 days.

Remarks.—The man had no employment. "One woman did dressmaking when she could obtain it to do; another went out washing: the third was a partial invalid." During the two weeks' investigation twenty-one meals were taken by the women away from home. These are not included in the number above.

Table 18.

Cost and weights of food materials used in dietary No. 23.

Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.
Beef.		$					$		
Round steak *(a)*,	28	.14	1	3.0	Eggs, - - -	54	.05	—	5.0
Round steak *(a)*,	29	.06	–	7.5	Butter, - -	M	.73	2	7.0
Short steak (loin),	M	.13	–	10.0	Milk, - - -	M	1.56	26	—
Tripe, - - -	33	.05	1	—	Condensed milk, -	M	.05	—	9.5
Corned, - -	34	.24	3	—	Buckwheat, prepared *(a)*, -	62	.12	1	3.0
Veal.					Flour *(a)*, - -	66	.73	32	8.0
Neck, - - -	36	.10	1	12.0	Bread, - -	81	.40	8	15.5
Mutton.					Crackers, milk, -	83	.14	1	6.0
Chops *(a)*, - -	42	.06	–	8.0	Cake, - - -	86	.10	—	3.5
Chops *(a)*, - -	43	.09	–	12.0	Mince pie, - -	92	.36	3	12.0
Chops (avg. 42.43),	—	.12	1	—	Sugar, granulated,	M	.64	14	12.5
Neck, - - -	44	.10	2	8.0	Cabbage, - -	98	.05	1	8.0
Pork.					Onions, - -	100	.03	1	4.0
Sausage *(a)*, -	50	.15	1	8.5	Potatoes, - -	102	.30	24	—
Lard, - - -	M	.08	–	13.0	Apples, - -	107	.15	8	14.0
Fish.					Oranges, - -	115	.13	1	—
Cod, boneless, -	M	.03	–	4.5	Waste *(a)*, - -	119	—	—	2.5

TABLE 19.

Weights and percentages of food materials and nutritive ingredients used in dietary of a family in Hartford. Calculated for one man 10 days.

FOOD MATERIALS.	WEIGHTS IN POUNDS.				WEIGHTS IN GRAMS.			Cost.	Fuel Value.
	Total Food.	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.		
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Grams	Grams	$	Cal.
Beef, - - -	1.3	.20	.18	—	92	82	—	.13	—
Veal, - - -	.4	.05	.02	—	22	8	—	.02	—
Mutton, - - -	1.0	.13	.21	—	59	97	—	.08	—
Pork, - - -	.5	.05	.35	—	24	157	—	.05	—
Poultry, - - -	—	—	—	—	—	—	—	—	—
Fish, etc., - -	—	.01	—	—	6	—	—	.01	—
Eggs, - - -	.1	.01	.01	—	4	3	—	.01	—
Butter, - - -	.5	—	.42	—	—	190	—	.15	—
Cheese, - - -	—	—	—	—	—	—	—	—	—
Milk, - - -	5.5	.19	.22	.34	86	102	152	.33	—
Total animal food,	9.3	.64	1.41	.34	293	639	152	.78	7760
Vegetable Food.									
Corn meal, rye flour, & buckwheat flour,	.2	.02	—	.19	9	1	84	.03	—
Wheat flours, - -	6.8	.89	.08	5.08	406	37	2306	.15	—
Oatmeal, rice, and wheat preparations,	—	—	—	—	—	—	—	—	—
Bread, crackers, etc.,	3.0	.26	.16	1.50	117	72	682	.21	—
Sugar and starches,	3.1	—	—	3.08	—	—	1397	.13	—
Total cereals, etc.,	13.1	1.17	.24	9.85	532	110	4469	.52	—
Beans and peas, -	—	—	—	—	—	—	—	—	—
Potatoes, - -	5.0	.09	.01	.76	41	2	347	.06	—
Other vegetables, -	.6	.01	—	.04	4	1	17	.02	—
Total vegetables, -	5.6	.10	.01	.80	45	3	364	.08	—
Fruits, - - -	2.0	.01	.01	.24	4	4	111	.06	—
Total vege'ble food,	20.7	1.28	.26	10.89	581	117	4944	.66	23740
Total food, - -	30.0	1.92	1.67	11.23	874	756	5096	1.44	31500
Percentages total food.	%	%	%	%				%	%
Beef, veal, & mutton,	8.9	19.8	24.8	—	—	—	—	15.8	—
Pork, - - -	1.6	2.8	20.7	—	—	—	—	3.4	—
Poultry, - - -	—	—	—	—	—	—	—	—	—
Fish, etc., - -	.2	.7	—	—	—	—	—	.4	—
Eggs, - - -	.2	.4	.4	—	—	—	—	.7	—
Butter, - - -	1.7	—	25.1	—	—	—	—	10.6	—
Cheese, - - -	—	—	—	—	—	—	—	—	—
Milk, - - -	18.4	9.8	13.5	3.0	—	—	—	23.4	—
Total animal food,	31.0	33.5	84.5	3.0	—	—	—	54.3	24.6
Cereals, sugars, etc.,	43.6	60.9	14.6	87.7	—	—	—	36.1	—
Vegetables, -	18.5	5.2	.4	7.1	—	—	—	5.5	—
Fruits, - - -	6.9	.4	.5	2.2	—	—	—	4.1	—
Total vege'ble food,	69.0	66.5	15.5	97.0	—	—	—	45.7	75.4
Total food, - -	100.0	100.0	100.0	100.0	—	—	—	100.0	100.0

TABLE 20.

Nutrients and potential energy in food purchased, rejected, and eaten in dietary of a family in Hartford, Conn.

FOOD MATERIALS.		Cost.	Nutrients. Protein.	Nutrients. Fat.	Nutrients. Carbo-hydrates.	Fuel Value.
For Family, 14 Days.		$	Grams.	Grams.	Grams.	Calories.
Food purchased,	Animal,	3.74	1405	3067	732	37280
	Vegetable,	3.15	2787	561	23736	113960
	Total,	6.89	4192	3628	24468	151240
Total waste,		—	14	20	33	380
Total food actually eaten,		6.89	4178	3608	24435	150860
Per Man per Day.						
Food purchased,	Animal,	.08	29	64	15	775
	Vegetable,	.06	58	12	495	2380
	Total,	.14	87	76	510	3155
Total waste,		—	—	1	1	15
Total food actually eaten,		.14	87	75	509	3140
Percentages of Total Food Purchased.		%	%	%	%	%
Food purchased,	Animal,	54.3	33.5	84.5	3.0	24.6
	Vegetable,	45.7	66.5	15.5	97.0	75.4
	Total,	100.0	100.0	100.0	100.0	100.0
Total waste,		—	.3	.6	.1	.2
Total food actually eaten,		100.0	99.7	99.4	99.9	99.8

No. 24. DIETARY OF A LABORER'S FAMILY, IN HARTFORD, CONNECTICUT.

The study began December, 1894, and continued 14 days. The members of the family and number of meals taken were as follows:

Man, - - - - - - - - - -	42 meals.
Woman, (42 x .8) equivalent to - - - - -	34 meals.
Girl, 11 years old (42 x .6) equivalent to - - - -	25 meals.
Girl, 6 years old (42 x .5), equivalent to - - - -	21 meals.
Girl 4 years old (42 x .4), equivalent to - - - -	17 meals.
Boy, 2½ years old (42 x .4), equivalent to - - -	17 meals.
Infant, equivalent to - - - - - - -	12 meals.
Total number of meals taken equivalent to - -	168 meals.
Equivalent to one man 56 days.	

Remarks.—The father was a laborer in a coal yard, earning $8.00 per week when working full time. During the two weeks of this study he earned $8.83. The mother worked in the laundry when possible.

"They pay $8.00 per month rent for four rooms and a small shed room on the second floor. The rooms are decently furnished, and, being small, three of the rooms are warmed in winter by the cook stove. The mother before marriage worked as a servant, and understands cooking."

"The children are kept in the house nearly all the time, as the mother said they learned 'bad ways' if they played with the other children."

The father is an Irish-American, the mother was born in England.

Table 21.

Cost and weights of food materials in dietary of a laborer's family in Hartford, Conn.

Food Materials.	Ref. No.	Cost.	Weight.		Food Materials.	Ref. No.	Cost.	Weight.	
		$	Lbs.	Ozs.			$	Lbs.	Ozs.
Beef.									
Neck, - - -	M	.20	2	—	Eggs, - -	54	.25	1	5.0
Shoulder steak *(a)*,	32	.55	5	—	Butter, - -	M	.65	2	—
Bologna sausage, -	35	.10	1	—	Milk, - -	M	.98	30	9.0
Suet, - - -	M	.02	—	6.0	Flour *(a)*, -	67	.50	22	10.0
Veal.					Rice, - - -	77	.23	2	14.0
Shoulder, - -	37	.32	4	—	Rolled oats *(a)*, -	76	.14	2	5.5
Mutton.					Bread, - -	81	.85	13	2.0
Neck, - - -	44	.30	5	—	Cookies and doughnuts, -	90	.21	1	9.5
Breast, - -	M	.18	3	—	Sugar, granulated,	M	.55	11	—
Pluck, - - -	45	.25	5	—	Beans, dried, -	M	.20	3	13.5
Pork.					Onions, - -	100	.07	6	12.0
Spare rib *(a)*, -	46	.43	5	—	Potatoes, - -	102	.66	51	12.0
Ham, edible portion *(a)*, - -	M	.91	5	7.5	Raisins, - -	24	.10	1	—
Salt, fat, - -	48	.18	1	8.0	Waste *(a)*, -	120	—	—	8.5
Fish.									
Cod, salt, - -	M	.30	3	—					

TABLE 22.

Weights and percentages of food materials and nutritive ingredients used in dietary of a laborer's family in Hartford. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Wts. in Grams.			Cost.	Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.		
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Gr.	Gr.	Gr.	Cts.	Cal.
Beef, - - - - -	1.5	.25	.24	—	113	110	—	.16	—
Veal, - - - - -	.7	.12	.06	—	54	28	—	.06	—
Mutton, - - - -	2.3	.36	.38	.03	164	171	14	.13	—
Pork, - - - - -	2.1	.28	.85	—	129	384	—	.27	—
Poultry, - - - -	—	—	—	—	—	—	—	—	—
Fish, etc., - - - -	.5	.09	—	—	39	1	—	.05	—
Eggs, - - - - -	.2	.03	.02	—	14	10	—	.04	—
Butter, - - - - -	.4	—	.29	—	—	133	—	.12	—
Cheese, - - - - -	—	—	—	—	—	—	—	—	—
Milk and cream, - -	5.5	.17	.22	.30	78	99	136	.17	—
Total animal food, -	13.2	1.30	2.06	.33	591	936	150	1.00	11740
Vegetable Food.									
Corn meal, rye meal, and buckwheat flour, - -	—	—	—	—	—	—	—	—	—
Wheat flours, - -	4.1	.41	.05	3.11	185	24	1408	.09	—
Oatmeal, rice, and wheat preparations, - -	.9	.12	.04	.68	53	16	308	.06	—
Bread, crackers, etc., -	2.6	.24	.05	1.45	110	24	658	.19	—
Sugars and starches, -	2.0	—	—	1.96	—	—	891	.10	—
Total cereals and sugars,	9.6	.77	.14	7.20	348	64	3265	.44	—
Beans and peas, - -	.7	.15	.01	.41	69	6	184	.04	—
Potatoes, - - -	9.2	.17	.01	1.41	76	4	641	.12	—
Other vegetables, - -	1.2	.02	.01	.11	8	2	49	.01	—
Total vegetables, -	11.1	.34	.03	1.93	153	12	874	.17	—
Fruit, - - - - -	.2	—	.01	.13	2	4	61	.02	—
Total vegetable food, -	20.9	1.11	.18	9.26	503	80	4200	.63	20020
Total food, - -	34.1	2.41	2.24	9.59	1094	1016	4350	1.63	31760
Percentages of Total Food.	%	%	%	%	%	%	%	%	%
Beef, veal, and mutton, -	13.3	30.3	30.4	.3	—	—	—	21.0	—
Pork, - - - - -	6.3	11.8	37.9	—	—	—	—	16.7	—
Poultry, - - - -	—	—	—	—	—	—	—	—	—
Fish, etc., - - - -	1.5	3.5	.1	—	—	—	—	3.3	—
Eggs, - - - - -	.7	1.3	1.0	—	—	—	—	2.8	—
Butter, - - - - -	1.0	—	13.1	—	—	—	—	7.1	—
Cheese, - - - - -	—	—	—	—	—	—	—	—	—
Milk, - - - - -	16.0	7.1	9.7	3.2	—	—	—	10.7	—
Total animal food, -	38.8	54.0	92.2	3.5	—	—	—	61.6	37.0

TABLE 22.—(*Continued.*)

Food Materials.	Weights in Pounds.				Wts. in Grams.			Cost.	Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.		
Percentages of Total Food. (Continued.)	Lbs.	Lbs.	Lbs.	Lbs.	Gr.	Gr.	Gr.	Cts.	Cal.
Cereals, sugars, etc., -	28.1	31.8	6.2	75.0	—	—	—	27.1	—
Vegetables, - - -	32.6	14.0	1.2	20.1	—	—	—	10.2	—
Fruits, - - - -	.5	.2	.4	1.4	—	—	—	1.1	—
Total vegetable food, -	61.2	46.0	7.8	96.5	—	—	—	38.4	63.0
Total food, - -	100.0	100.0	100.0	100.0	—	—	—	100.0	100.0

TABLE 23.

Nutrients and potential energy in food purchased, rejected and eaten in dietary of a laborer's family in Hartford, Conn.

Food Materials.		Cost.	Nutrients.			Fuel Value.
			Protein.	Fat.	Carbo-hydrates.	
For Family, 14 Days.		$	Grams.	Grams.	Grams.	Calories.
Food purchased, -	Animal, -	5.62	3312	5239	1076	66710
	Vegetable, -	3.51	2816	444	23519	112100
	Total, -	9.13	6128	5683	24595	178810
Waste, - - - -	Total, -	—	38	99	98	1480
Food actually eaten, - -	Total, -	9.13	6090	5584	24497	177330
Per Man per Day.						
Food purchased, -	Animal, -	.10	59	94	15	1175
	Vegetable, -	.06	50	8	420	2000
	Total, -	.16	109	102	435	3175
Waste, - - - -	Total, -	—	1	2	2	30
Food actually eaten, - -	Total, -	.16	108	100	433	3165
Percentages of Total Food Purchased.		%	%	%	%	%
Food purchased, -	Animal, -	61.6	54.0	92.2	3.5	37.3
	Vegetable, -	38.4	46.0	7.8	96.5	62.7
	Total, -	100.0	100.0	100.0	100.0	100.0
Waste, - - - -	Total, -	—	.6	1.7	.4	.8
Food actually eaten, - -	Total, -	100.0	99.4	98.3	99.6	99.2

No. 156. DIETARY OF A FARMER'S FAMILY IN CONNECTICUT.

(Same Family as Dietary No. 120.)

The study began April 17, 1896, and continued 10 days. The members of the family and number of meals taken were as follows:

Man, about 60 years old, - - - - - - -	30 meals.
Man, 35 years old, - - - - - - - - -	30 meals.
Man, 30 years old, - - - - - - - - -	30 meals.
Woman, about 60 years old (30 x .8), equivalent to - -	24 meals.
Woman, about 30 years old (30 x .8), equivalent to - -	24 meals.
Girl, 7 years old (30 x .5), equivalent to - - - - -	15 meals.
Girl, 4 years old (30 x .4), equivalent to - - - - -	12 meals.
Total number of meals taken equivalent to - -	165 meals.

Equivalent to one man 55 days.

Remarks.—The family consisted of a man and his wife, two sons, a daughter-in-law, and two grand-children.

Table 24.

Weights of food materials used in dietary of a farmer's family in Connecticut.

Food Materials.	Reference No.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Reference No.	Weight. Pounds.	Weight. Ounces.
*Beef.**							
Sirloin (loin), -	M	6	8.0	Flour, pastry *(a)*,	70	6	8.0
Round steak, -	1	2	—	Flour, entire wheat,	M	2	—
Shoulder clod, -	M	4	—	Flour, buckwheat,	63	1	12.5
Rump, - - -	2	4	—	Corn meal, - -	64	1	6.5
Corned, - -	3	3	.5	Rolled oats, - -	74	1	5.0
Dried and smoked,	M	—	8.5	Sugar, granulated,	M	10	—
				Sugar, brown, -	M	1	3.0
Pork.				Molasses, - -	93	1	2.0
Smoked shoulder, -	M	4	11.0	Crackers, - -	83	1	6.5
Fat, salt, - -	48	7	13.5	Rice, - - -	77	—	10.0
Lard, - - -	M	2	4.5	Gingerbread, -	89	1	—
				Sugar cookies, -	90	2	3.0
Fish.				Doughnuts, - -	91	2	—
Haddock, fresh, -	M	4	—	Maple syrup, -	M	4	5.0
Cod, salt, boneless,	M	1	8.5	Beans, dried, -	M	3	7.5
Mackerel, salt, -	M	2	8.0	Potatoes, edible portion, - -	16	36	8.0
Eggs, - - -	54	5	1.0	Parsnips, edible portion, - -	14	6	—
Butter, - - -	M	4	10.0	Squash, canned, -	M	2	—
Cheese, - - -	55	—	10.5	Potato chips, -	103	—	8.0
Milk *(a)*, - -	58	84	4.0	Spinach, - -	104	3	—
Milk, skimmed, not eaten *(a)*, - -	61	31	11.0	Bananas, - -	109	10	—
				Oranges, - -	115	9	5.0
Animal waste *(a)*,	121	5	6.5	Quince jelly,† -	113	1	6.5
Vegetable waste *(a)*,	122	5	7.5	Currants, dried, -	112	—	5.0
				Raisins, - -	24	—	5.0
Flour, bread *(a)*, -	68	8	—	Prunes, - -	116	2	11.0

* The weights of all meats are without bone. † Composition assumed.

TABLE 25.

Weights and percentages of food materials and nutritive ingredients used in dietary of a farmer's family. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Weights in Grams.			Fuel Value.
	Total Wgt. Food.	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.	
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Grams.	Grams.	Grams.	Calories
Beef, - - - - -	3.64	.67	.70	—	303	319	—	—
Veal, - - - - -	—	—	—	—	—	—	—	—
Mutton, - - - -	—	—	—	—	—	—	—	—
Pork, - - - - -	2.69	.16	1.94	—	73	877	—	—
Poultry, - - - -	—	—	—	—	—	—	—	—
Fish, etc., - - - -	1.46	.20	.08	—	90	37	—	—
Eggs, - - - -	.93	.11	.09	—	55	40	—	—
Butter, - - - -	.84	—	.69	—	—	314	—	—
Cheese, - - - -	.12	.03	.04	—	14	18	1	—
Milk and cream, - -	9.55	.31	.70	.48	139	317	219	—
Total animal food, -	19.23	1.48	4.24	.48	674	1922	220	21540
Vegetable Food.								
Corn meal, rye meal, and buckwheat flour, -	.58	.04	.01	.44	19	4	201	—
Wheat flours, - -	3.00	.37	.02	2.26	169	9	1024	—
Oatmeal, rice, and wheat preparations, - -	.35	.05	.02	.25	22	8	113	—
Bread, crackers, etc., -	1.20	.09	.16	.79	39	75	357	—
Sugars and starches, -	3.02	.01	—	2.71	3	—	1230	—
Total cereals and sugars	8.15	.56	.21	6.45	252	96	2925	—
Beans and peas, - -	.63	.14	.01	.37	64	5	169	—
Potatoes, - - - -	6.72	.15	.04	1.25	67	18	567	—
Other vegetables, -	2.00	.03	.01	.23	15	5	104	—
Total vegetables, -	9.35	.32	.06	1.85	146	28	840	—
Fruit, - - - - -	4.37	.04	.03	.93	17	11	421	—
Total vegetable food,	21.87	.92	.30	9.23	415	135	4186	20100
Total food, - -	41.10	2.40	4.54	9.71	1089	2057	4406	41640
Percentages Total Food.	%	%	%	%				%
Beef, veal, and mutton,	8.9	27.8	15.5	—	—	—	—	—
Pork, - - - - -	6.6	6.7	42.7	—	—	—	—	—
Poultry, - - - -	—	—	—	—	—	—	—	—
Fish, etc., - - - -	3.6	8.3	1.8	—	—	—	—	—
Eggs, - - - - -	2.2	5.0	1.9	—	—	—	—	—
Butter, - - - -	2.0	—	15.3	—	—	—	—	—
Cheese, - - - -	.3	1.3	.9	—	—	—	—	—
Milk, - - - - -	23.2	12.8	15.4	5.0	—	—	—	—
Total animal food, -	46.8	61.9	93.5	5.0	—	—	—	51.7
Cereals, sugars, etc., -	19.8	23.1	4.7	66.4	—	—	—	—
Vegetables, - - -	22.8	13.4	1.3	19.1	—	—	—	—
Fruits, . - - -	10.6	1.6	.5	9.5	—	—	—	—
Total vegetable food,	53.2	38.1	6.5	95.0	—	—	—	48.3
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	100.0

TABLE 26.

Nutrients and potential energy in food purchased, rejected, and eaten in dietary of a farmer's family in Connecticut.

FOOD MATERIALS.		Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
For Family, 10 days.		Grams.	Grams.	Grams.	Calories.
Food purchased,	Animal,	3707	10566	1214	118440
	Vegetable,	2282	741	23019	110630
	Total,	5989	11307	24233	229070
Waste,	Animal,	501	*	221	—
	Vegetable,	324	*	1723	—
	Total,	825	1573	1944	25985
Food actually eaten,	Animal,	3206	*	993	—
	Vegetable,	1958	*	21296	—
	Total,	5164	9734	22289	203085
Per Man per Day.					
Food purchased,	Animal,	67	192	22	2150
	Vegetable,	42	14	419	2020
	Total,	109	206	441	4170
Waste,	Animal,	9	*	4	—
	Vegetable,	6	*	31	—
	Total,	15	29	35	475
Food actually eaten,	Animal,	58	*	18	—
	Vegetable,	36	*	388	—
	Total,	94	177	406	3695
Percentages of Total Food Purchased.		%	%	%	%
Food purchased,	Animal,	61.9	93.5	5.0	51.7
	Vegetable,	38.1	6.5	95.0	48.3
	Total,	100.0	100.0	100.0	100.0
Waste,	Animal,	8.4	*	.9	—
	Vegetable,	5.4	*	7.1	—
	Total,	13.8	13.9	8.0	11.3
Food actually eaten,	Animal,	53.5	*	4.1	—
	Vegetable,	32.7	*	87.9	—
	Total,	86.2	86.1	92.0	88.7

* The animal and vegetable wastes were kept separate, but inasmuch as more or less animal fat used in cooking must occur in the vegetable waste, the analysis does not show the real amount of vegetable fat wasted. For this reason no attempt is made to distinguish between animal and vegetable fat in the waste, and consequently the fuel value of the animal and vegetable waste cannot be calculated.

No. 157. DIETARY OF A FARMER'S FAMILY IN CONNECTICUT.

(Same Family as No. 121.)

The study began May 4, 1896, and continued 10 days. The family consisted of a man, his wife and his two sisters. The number of meals taken were as follows:

Man, about 40 years old, - - - - - - - -	30 meals.
Woman, about 35 years old (30 x .8), equivalent to - -	24 meals.
Woman, about 42 years old (30 x .8), equivalent to - -	24 meals.
Woman, about 35 years old (30 x .8), equivalent to - -	24 meals.
Total number of meals taken equivalent to - - -	102 meals.

Equivalent to one man 34 days.

Remarks.—"The man rented his farm, and at the time of the dietary did about two days' work per week. The women had quite active exercise. With the exception of the wife, all were below the average weight. The health of all was fair." The man weighed about 135 lbs., and the women about 150, 100, and 110 lbs., respectively.

Table 27.

Weights of food materials used in dietary of a farmer's family in Connecticut.

Food Materials.	Reference No.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Reference No.	Weight. Pounds.	Weight. Ounces.
*Beef.**				Eggs, - - -	54	3	—
				Butter, - - -	M	4	—
Short steak (loin), -	M	4	12.0	Milk *(a)*, -	59	22	—
Shoulder clod, - -	M	4	—	Skim milk *(a)*, -	61	7	4.0
				Flour, pastry *(a)*, -	71	17	8.0
Veal.				Rolled oats, - -	74	—	14.5
Steak, - - -	M	1	2.0	Cookies, sugar, -	90	1	—
				Crackers, milk, - -	83	1	—
Lamb.				Sugar, granulated, -	M	5	—
				Sugar, brown, - -	M	—	12.0
Chops, - - -	6	1	14.5	Molasses, - - -	93	—	4.0
				Tapioca, - - -	M	—	3.0
Pork.				Potatoes, edible portion, - - -	16	21	12.0
Ham, - - -	M	4	3.0	Asparagus, - -	97	3	4.0
Bacon, - - -	9	—	9.0	Rhubarb, - - -	M	2	—
Lard, - - -	M	1	1.0	Cocoanut, shredded, -	118	—	4.0

* The weights of all meats are without bone.

TABLE 28.

Weights and percentages of food materials and nutritive ingredients used in dietary of a farmer's family. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Weights in Grams.			Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.	
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Gr.	Gr.	Gr.	Cal.
Beef, - - - - -	2.6	.48	.41	—	219	188	—	—
Veal, - - - - -	.3	.07	.03	—	31	15	—	—
Mutton, - - - - -	.5	.10	.16	—	45	72	—	—
Pork, - - - - -	1.7	.21	.91	—	94	411	—	—
Poultry, - - - - -	—	—	—	—	—	—	—	—
Fish, etc., - - - -	—	—	—	—	—	—	—	—
Eggs, - - - - -	.9	.11	.08	—	52	38	—	—
Butter, - - - - -	1.2	—	.97	—	—	440	—	—
Cheese, - - - - -	—	—	—	—	—	—	—	—
Milk and skim milk, - -	8.6	.32	.35	.30	145	157	137	—
Total animal food, - -	15.8	1.29	2.91	.30	586	1321	137	15250
Vegetable Food.								
Corn meal, rye meal, and buckwheat flour, - -	—	—	—	—	—	—	—	—
Wheat flours, - - - -	5.1	.57	.01	3.93	259	7	1784	—
Oatmeal, rice, and wheat preparation, - - -	.3	.05	.02	.18	21	8	81	—
Bread, crackers, etc., - -	.6	.05	.07	.43	21	30	194	—
Sugars and starches, - -	1.8	—	—	1.78	1	—	808	—
Total cereals and sugars,	7.8	.67	.10	6.32	302	45	2867	—
Beans and peas, - -	—	—	—	—	—	—	—	—
Potatoes, - - - - -	6.4	.13	.01	1.15	61	3	522	—
Other vegetables, - -	1.5	.02	—	.05	9	2	20	—
Total vegetables, - -	7.9	.15	.01	1.20	70	5	542	—
Fruit, - - - - -	.1	.01	.04	.02	2	19	11	—
Total vegetable food, -	15.8	.83	.15	7.54	374	69	3420	16200
Total food, - - - -	31.6	2.12	3.06	7.84	960	1390	3557	31450
Percentages of Total Food.	%	%	%	%	%	%	%	%
Beef, veal, and mutton, -	11.0	30.7	19.8	—	—	—	—	—
Pork, - - - - -	5.4	9.8	29.5	—	—	—	—	—
Poultry, - - - - -	—	—	—	—	—	—	—	—
Fish, etc., - - - -	—	—	—	—	—	—	—	—
Eggs, - - - - -	2.8	5.5	2.7	—	—	—	—	—
Butter, - - - - -	3.7	—	31.7	—	—	—	—	—
Cheese, - - - - -	—	—	—	—	—	—	—	—
Milk and skim milk, - -	27.1	15.0	11.3	3.9	—	—	—	—
Total animal food, -	50.0	61.0	95.0	3.9	—	—	—	48.5

TABLE 28.—*(Continued.)*

FOOD MATERIALS.	WEIGHTS IN POUNDS. Total Weight of Food.	Protein.	Fat.	Carbo-hydrates.	WEIGHT IN GRAMS. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Percentages of Total Food. (Continued.)	%	%	%	%	%	%	%	%
Cereals, sugars, etc., - -	24.7	31.5	3.3	80.6	—	—	—	—
Vegetables, - - -	25.1	7.3	.3	15.2	—	—	—	—
Fruits, - - - - -	.2	.2	1.4	.3	—	—	—	—
Total vegetable food, -	50.0	39.0	5.0	96.1	—	—	—	51.5
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	100.0

TABLE 29.

Nutrients and potential energy in food purchased, rejected, and eaten in dietary of a farmer's family in Connecticut.

FOOD MATERIALS.		NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
For Family, 10 Days.		Grams.	Grams.	Grams.	Calories
Food purchased and eaten,* -	Animal, -	1992	4492	471	51870
	Vegetable, -	1272	236	11627	55080
	Total, -	3264	4728	12098	106950
Per Man per Day.					
Food purchased and eaten, -	Animal, -	59	132	14	1525
	Vegetable, -	37	7	342	1620
	Total, -	96	139	356	3145
Percentages of Total Food Purchased.		%	%	%	%
Food purchased and eaten, -	Animal, -	61.0	95.0	3.9	48.5
	Vegetable, -	39.0	5.0	96.1	51.5
	Total, -	100.0	100.0	100.0	100.0

* There was no waste in this dietary.

No. 169. DIETARY OF THE STATION AGRICULTURIST'S FAMILY.

The study began November 9, 1895, and continued 28 days. The members of the family and number of meals taken were as follows:

Man, 34 years old; weight, 185 lbs., - - - - -	78 meals.
Woman, 28 years old; weight, 140 lbs. (81 x .8), equivalent to	65 meals.
Child, 3½ years old; weight, 41 lbs. (83 x .4), equivalent to	33 meals.
Child, 2 years old; weight, 34 lbs. (82 x .4), equivalent to -	33 meals.
Servant, 60 years old; weight, 145 lbs. (82 x .8), equivalent to	66 meals.
Visitor, male, - - - - - - - - - -	2 meals.
Total number of meals taken equivalent to - -	277 meals.

Equivalent to one man 92 days.

Table 30.

Cost and weights of food materials used in dietary of the Station Agriculturist's family.

Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.
Beef.		$		
Loin,	M	.32	2	.5
Shoulder,	M	.56	4	10.0
Round,	27	.71	5	15.5
Round, 2d cut,	30	.32	3	9.0
Rump,	31	.54	5	7.0
Fore shank,	M	.38	9	9.0
Sirloin steak (loin),	M	.31	1	14.5
Dried and smoked,	M	.10	—	9.0
Lamb.				
Hind leg,	38	.34	3	6.0
Side, without tallow,	39	.82	10	3.5
Pork.				
Ham,	M	.08	—	12.0
Lard and cottolene,	M	.51	1	5.5
Poultry.				
Chicken, ed. portion,	M	.39	2	4.5
Fish.				
Halibut steak,	M	.60	2	15.5
Mackerel, fresh,	M	.11	—	10.0
Cod, salt, boneless,	M	.04	—	11.5
Eggs,	54	.16	—	12.5
Butter,	M	2.38	8	8.0
Cheese,	55	.12	—	10.5
Cheese, cottage,	56	.10	—	9.0
Milk,	M	2.94	147	1.5
Accumulated fat not used,	127	—	1	8.5
Corn meal,	64	—	—	3.0
Wheat preparations,	M	.58	6	14.5
Oatmeal,	74	.01	—	2.5
Flour, bread,	65	.60	29	13.5
Flour, pastry,	69	.22	11	13.5
Mellin's food,	78	.59	1	1.5
Crackers, milk,	83	.37	4	7.0

Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.
		$		
Chocolate cake,	88	.06	—	3.0
Macaroni,	80	.09	—	8.0
Rice,	77	.08	—	15.0
Sugar, granulated,	M	1.00	17	—
Sugar, maple,	M	.02	—	2.0
Syrup, maple,	M	.08	—	15.5
Molasses,	93	.17	2	12.5
Honey,	94	.07	—	6.0
Cocoa,	M	.05	—	2.0
Beans, dried,	M	.05	1	1.5
Carrots (43 % refuse),	11	.01	—	3.0
Celery (12 % refuse),	12	.30	2	9.5
Onions (11.6 % refuse),	13	.03	—	13.5
Potatoes (23.7 % refuse),	16	.26	29	3.5
Potatoes (15% refuse)	16	.03	4	4.0
Sweet potatoes (21 % refuse),	17	.06	2	—
Squash (36.3 % refuse),	18	.20	9	15.5
Turnips (23% refuse)	19	.04	3	10.0
Tomatoes, canned,	106	.10	1	2.5
Apples, wormy (41 % refuse),	20	.42	16	7.0
Apples, good (23.4 % refuse),	20	.11	5	6.5
Bananas (25% refuse)	21	.25	1	2.0
Grapes (19 % refuse),	22	.65	11	—
Raisins (18.7 % refuse),	24	.05	—	4.5
Canned fruit,*	114	2.25	8	15.5
Crab apple jelly,†	113	.05	—	10.0
Waste *(a)*,	123	—	1	6.5

* Composition assumed; home canned; cost of fruit and sugar estimated at 25 cents per quart can. † Composition assumed.

Table 31.

Weights and percentages of food materials and nutritive ingredients used in dietary of the Station Agriculturist's family. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Wts. in Grams.			Cost.	Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.		
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Gr.	Gr.	Gr.	$	Cal.
Beef,	3.7	.55	.43	—	248	194	—	.35	—
Veal,	—	—	—	—	—	—	—	—	—
Mutton,	1.5	.21	.26	—	97	117	—	.13	—
Pork,	.2	.01	.17	—	5	79	—	.06	—
Poultry,	.2	.05	.04	—	21	17	—	.04	—
Fish, etc.,	.5	.07	.02	—	34	8	—	.08	—
Eggs,	.1	.01	.01	—	5	3	—	.02	—
Butter,	.9	—	.76	—	—	346	—	.26	—
Cheese,	.1	.04	.03	.04	19	16	16	.03	—
Milk and cream,	16.0	.53	.64	.80	239	290	363	.32	—
Total animal food,	23.2	1.47	2.36	.84	668	1070	379	1.29	—
Accumulated fat not used,	.2	—	.16	—	—	73	—	—	—
Total animal food used,	23.0	1.47	2.20	.84	668	997	379	1.29	13560
Vegetable Food.									
Corn meal, rye meal, and buckwheat flour,	—	—	—	.01	1	—	6	—	—
Wheat flours,	4.5	.50	.05	3.39	227	22	1538	.09	—
Oatmeal, rice, and wheat preparations,	1.0	.11	.01	.75	49	6	342	.14	—
Bread, crackers, etc.,	.6	.05	.07	.39	24	30	176	.05	—
Sugars and starches,	2.3	.01	—	2.18	5	2	988	.15	—
Total cereals and sugars,	8.4	.67	.13	6.72	306	60	3050	.43	—
Beans and peas,	.1	.03	—	.07	12	1	32	.01	—
Potatoes,	3.9	.08	.01	.72	36	2	324	.04	—
Other vegetables,	2.0	.03	.01	.17	14	4	78	.07	—
Total vegetables,	6.0	.14	.02	.96	62	7	434	.12	—
Fruit,	4.8	.03	.04	1.06	15	19	482	.41	—
Total vegetable food,	19.2	.84	.19	8.74	383	86	3966	.96	18630
Total food,	42.2	2.31	2.39	9.58	1051	1083	4345	2.25	32190
Percentages of Total Food.	%	%	%	%	%	%	%	%	%
Beef, veal, and mutton,	12.2	32.8	28.7	—	—	—	—	21.3	—
Pork,	.5	.5	7.3	—	—	—	—	2.8	—
Poultry,	.6	2.0	1.6	—	—	—	—	1.9	—
Fish, etc.,	1.1	3.2	.7	—	—	—	—	3.6	—
Eggs,	.2	.5	.3	—	—	—	—	.8	—
Butter,	2.2	—	31.9	—	—	—	—	11.5	—

TABLE 31.—*(Continued.)*

FOOD MATERIALS.	WEIGHTS IN POUNDS.				WTS. IN GRAMS.			Cost.	Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.		
Percentages of Total Food. (Continued.)	%	%	%	%	%	%	%	%	%
Cheese, - - - -	.3	1.8	1.5	.4	—	—	—	1.1	—
Milk, - - - -	37.9	22.7	26.8	8.3	—	—	—	14.2	—
Total animal food, -	55.0	63.5	98.8	8.7	—	—	—	57.2	—
Accumulated fat not used,	.4	—	6.7	—	—	—	—	—	—
Total animal food used,	54.6	63.5	92.1	8.7	—	—	—	57.2	42.1
Cereals, sugars, etc., -	19.9	29.1	5.6	70.2	—	—	—	19.3	—
Vegetables, - - -	14.2	5.9	.6	10.0	—	—	—	5.2	—
Fruits, - - - -	11.3	1.5	1.7	11.1	—	—	—	18.3	—
Total vegetable food, -	45.4	36.5	7.9	91.3	—	—	—	42.8	57.9
Total food, - -	100.0	100.0	100.0	100.0	—	—	—	100.0	100.0

TABLE 32.

Nutrients and potential energy in food purchased, rejected, and eaten in dietary of the Station Agriculturist's family.

Food Materials.		Cost.	Nutrients. Protein.	Nutrients. Fat.	Nutrients. Carbohydrates.	Fuel Value.
For Family, 28 Days.		$	Grams.	Grams.	Grams.	Calories
Food purchased	Animal	11.83	6144	9175	3487	124810
	Vegetable	8.85	3528	789	36487	171400
	Total	20.68	9672	9964	39974	296210
Waste	Animal	—	79	213	20	2390
	Vegetable	—	45	18	204	1190
	Total	—	124	231	224	3580
Food actually eaten	Animal	—	6065	8962	3467	122420
	Vegetable	—	3483	771	36283	170210
	Total	—	9548	9733	39750	292630
Per Man per Day.						
Food purchased	Animal	.13	67	100	38	1360
	Vegetable	.09	38	8	397	1860
	Total	.22	105	108	435	3220
Waste	Animal	—	1	3	—	30
	Vegetable	—	—	—	2	10
	Total	—	1	3	2	40
Food actually eaten	Animal	—	66	97	38	1330
	Vegetable	—	38	8	395	1850
	Total	—	104	105	433	3180
Percentages of Total Food Purchased.		%	%	%	%	%
Food purchased	Animal	57.2	63.5	92.1	8.7	42.1
	Vegetable	42.8	36.5	7.9	91.3	57.9
	Total	100.0	100.0	100.0	100.0	100.0
Waste	Animal	—	.8	2.1	.1	.8
	Vegetable	—	.5	.2	.5	.4
	Total	—	1.3	2.3	.6	1.2
Food actually eaten	Animal	—	62.7	90.0	8.6	41.3
	Vegetable	—	36.0	7.7	90.8	57.5
	Total	—	98.7	97.7	99.4	98.8

No. 173. DIETARY OF A PRIVATE BOARDING HOUSE IN MIDDLETOWN, CONN.

The study began October 19, 1896, and continued 7 days. The members of the household consisted of seven adults, two men and five women. One man was elderly and not engaged in any active work; the other was a young and active clergyman. Two of the women were middle aged and three young. All were in good health and actively occupied. The number of meals taken was as follows:

Two men, - - - - - - - - - -	39 meals.
Five women (105 x .8), equivalent to - - - -	84 meals.
Total number of meals taken equivalent to - -	123 meals.

Equivalent to one man 41 days.

TABLE 33.

Cost and weights of food materials used in dietary of private boarding house in Middletown, Conn.

FOOD MATERIALS.	Reference No.	Cost.	Weight	
			Pounds.	Ounces.
*Beef.**		$		
Sirloin steak,	M	1.40	6	8.0
Short steak,	M	.16	—	14.0
Shoulder,	M	.40	3	1.0
Dried and smoked,	M	.03	—	2.0
Veal.				
Rib roast,	4	.15	1	—
Lamb.				
Neck and shoulder,	7	.25	2	2.5
Leg,	5	.90	4	2.0
Pork.				
Salt, fat,	48	.01	—	2.0
Lard,	M	.16	1	6.5
Poultry.				
Chicken,	M	.72	2	15.5
Eggs,	10	.66	3	11.0
Butter,	M	1.04	3	15.5
Cheese,	55	.10	—	14.0
Cheese, cottage,	57	.05	—	6.0
Milk,	M	1.02	31	4.5
Cream,	M	.48	4	—
Corn meal,	64	.01	—	10.0
Flour, bread,	65	.20	9	1.0
Flour, pastry,	69	.03	—	14.5
Rolled oats,	74	.09	1	8.0
Rice,	77	.01	—	3.5

FOOD MATERIALS.	Reference No.	Cost.	Weight	
			Pounds.	Ounces.
		$		
Cake,	87	.49	2	7.5
Crackers,	84	.13	—	13.5
Macaroni,	80	.10	—	12.0
Sugar, granulated,	M	.39	7	3.0
Syrup, maple,	M	.18	1	8.0
Beans, dried,	M	.06	1	10.5
Celery (56 % refuse),	12	.09	—	6.0
Corn, canned,	M	.09	1	8.0
Onions (7.3 % refuse),	13	.03	1	11.0
Potatoes (17.6 % refuse)	16	.18	13	14.5
Sweet potatoes (20 % refuse),	17	.24	10	9.5
Tomatoes, canned,	106	.08	2	8.0
Apples (38 % refuse),	20	.08	4	10.5
Bananas (38 % refuse),	21	.22	1	15.0
Grapes (23.3 % refuse),	22	.15	1	10.0
Prunes (25.7 % refuse),	23	.15	1	2.0
Accessories.				
Catsup,	—	.02	—	4.5
Olives (27.5 % pit),	—	.17	—	5.0
Pickles,	—	.20	1	13.0
Coffee,	—	.18	—	11.5
Tea,	—	.15	—	5.5
Animal waste *(a)*,	124	—	1	1.5
Clear fat, waste *(a)*,	125	—	—	9.0
Vegetable waste *(a)*,	126	—	1	8.0

* All weights in this dietary are of the edible portion without refuse.

TABLE 34.

Weights and percentages of food materials and nutritive ingredients used in dietary of a private boarding house, Middletown, Conn. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Wts. in Grams.			Cost.	Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.		
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Gr.	Gr.	Gr.	$	Cal.
Beef,	2.6	.48	.45	—	219	204	—	.49	—
Veal,	.2	.05	.02	—	22	7	—	.04	—
Mutton,	1.5	.28	.32	—	126	146	—	.28	—
Pork,	.4	—	.38	—	—	169	—	.04	—
Poultry,	.7	.14	.11	—	63	50	—	.17	—
Fish, etc.,	—	—	—	—	—	—	—	—	—
Eggs,	.9	.13	.09	—	61	43	—	.16	—
Butter,	1.0	—	.80	—	—	361	—	.25	—
Cheese,	.3	.07	.10	.01	34	45	3	.04	—
Milk and cream,	8.6	.28	.48	.42	125	220	193	.37	—
Total animal food,	16.2	1.43	2.75	.43	650	1245	196	1.84	15050
Vegetable Food.									
Corn meal, rye meal, and buckwheat flour,	.1	.01	—	.11	6	1	51	—	—
Wheat flours,	2.5	.28	.03	1.82	124	12	824	.06	—
Oatmeal, rice, and wheat preparations,	.4	.07	.03	.29	30	12	131	.02	—
Bread, crackers, etc.,	1.0	.08	.08	.67	38	39	303	.18	—
Sugars and starches,	2.1	—	—	2.01	—	—	913	.14	—
Total cereals and sugars,	6.1	.44	.14	4.90	198	64	2222	.40	—
Beans and peas,	.4	.09	.01	.24	41	3	108	.02	—
Potatoes,	6.0	.12	.02	1.31	53	10	595	.10	—
Other vegetables,	1.5	.02	—	.14	12	3	63	.07	—
Total vegetables,	7.9	.23	.03	1.69	106	16	766	.19	—
Fruits,	2.3	.03	.02	.55	11	8	251	.14	—
Total vegetable food,	16.3	.70	.19	7.14	315	88	3239	.73	15390
Total food,	32.5	2.13	2.94	7.57	965	1333	3435	2.57	30440
Accessories,	.8	—	—	—	—	—	—	—	—
Percentages of Total Food.	%	%	%	%	%	%	%	%	%
Beef, veal, and mutton,	13.1	38.2	26.7	—	—	—	—	29.2	—
Pork,	1.1	—	12.7	—	—	—	—	1.5	—
Poultry,	2.2	6.5	3.8	—	—	—	—	6.4	—
Fish, etc.,	—	—	—	—	—	—	—	—	—
Eggs,	2.7	6.3	3.2	—	—	—	—	5.9	—
Butter,	2.9	—	27.1	—	—	—	—	9.2	—
Cheese,	.9	3.5	3.4	.1	—	—	—	1.3	—
Milk and cream,	25.8	12.9	16.5	5.6	—	—	—	13.4	—
Total animal food,	48.7	67.4	93.4	5.7	—	—	—	66.9	49.4
Cereals, sugars, etc.,	18.4	20.5	4.8	64.7	—	—	—	14.5	—
Vegetables,	23.6	11.0	1.2	22.3	—	—	—	6.9	—
Fruits,	6.8	1.1	.6	7.3	—	—	—	5.3	—
Total vegetable food,	48.8	32.6	6.6	94.3	—	—	—	26.7	50.6
Accessories,	2.5	—	—	—	—	—	—	6.4	—
Total food,	100.0	100.0	100.0	100.0	—	—	—	100.0	100.0

TABLE 35.

Nutrients and potential energy in food purchased, rejected, and eaten in dietary of a private boarding house, Middletown, Conn.

Food Materials.		Cost.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
		$	Grams.	Grams.	Grams.	Calories
For Family, 7 Days.						
Food purchased,	Animal,	7.53	2665	5103	803	61680
	Vegetable,	3.72	1290	363	13280	63110
	Total,	11.25	3955	5466	14083	124790
Waste,	Animal,	—	162	*	—	—
	Vegetable,	—	17	*	168	—
	Total,	—	179	561	168	6640
Food actually eaten,	Animal,	7.53	2503	*	803	—
	Vegetable,	3.72	1273	*	13112	—
	Total,	11.25	3776	4905	13915	118150
Per Man per Day.						
Food purchased,	Animal,	.18	65	124	19	1495
	Vegetable,	.09	31	9	324	1540
	Total,	.27	96	133	343	3035
Waste,	Animal,	—	4	*	—	—
	Vegetable,	—	—	*	4	—
	Total,	—	4	14	4	160
Food actually eaten,	Animal,	.18	61	*	19	—
	Vegetable,	.09	31	*	320	—
	Total,	.27	92	119	339	2875
Percentages of Total Food Purchased.		%	%	%	%	%
Food purchased,	Animal,	66.9	67.4	93.4	5.7	49.4
	Vegetable,	33.1	32.6	6.6	94.3	50.6
	Total,	100.0	100.0	100.0	100.0	100.0
Waste,	Animal,	—	4.1	*	—	—
	Vegetable,	—	.4	*	1.2	—
	Total,	—	4.5	10.3	1.2	5.3
Food actually eaten,	Animal,	66.9	63.3	*	5.7	—
	Vegetable,	33.1	32.2	*	93.1	—
	Total,	100.0	95.5	89.7	98.8	94.7

* The animal and vegetable wastes were kept separate, but inasmuch as more or less animal fat used in cooking must occur in the vegetable waste, the analysis does not show the real amount of vegetable fat. For this reason no attempt is made to distinguish between animal and vegetable fat, and consequently the fuel value of the animal and vegetable waste cannot be calculated.

No. 174. DIETARY OF A FARMER'S FAMILY IN VERMONT.

The study began July 7, 1896, and continued 15⅓ days. The members of the family and number of meals taken were as follows:

Man, about 45 years old, - - - - - - -	46 meals.
Woman, about 45 years old (46 x .8), equivalent to - -	37 meals.
Man, 22 years old, - - - - - - - - -	46 meals.
Boy, 19 years old, - - - - - - - - -	46 meals.
Boy, 15 years old (46 x .8), equivalent to - - - -	37 meals.
Girl, 16 years old (46 x .7), equivalent to - - - -	32 meals.
Girl, 14 years old (46 x .7), equivalent to - - - -	32 meals.
Girl, 4 years old (46 x .4), equivalent to - - - -	18 meals.
Total number of meals taken equivalent to - -	294 meals.

Equivalent to one man 98 days.

Remarks.—This is a summer dietary of the same family whose dietary in winter was given in the Report of the Station for 1895 as No. 27. The family were all at rather active exercise, as the study was made in one of the busy seasons of the year.

TABLE 36.

Cost and weights of food materials used in dietary of a farmer's family in Vermont.

Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.
Beef.		$		
Brisket, - - -	26	.30	4	12.0
Ribs, - - -	M	.60	6	—
Tripe, - - -	33	.59	9	13.0
Corned, canned, -	M	.25	2	—
Pork.				
Ham, - - -	M	.84	6	—
Salt, fat, - -	48	.60	6	—
Lard, - - -	M	.13	1	4.0
Fish.				
Salt cod, boneless,	M	.05	—	7.0
Eggs, - - -	54	1.75	14	—
Butter, - -	M	1.40	7	—
Cheese, - -	55	.15	1	4.0
Milk, whole,* -	60	1.40	70	—
Buttermilk, - -	M	.26	25	7.5
Sour milk,* - -	60	.05	4	8.0
Cream, - -	M	.30	3	—

Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.
		$		
Corn meal, - -	64	.21	13	12.0
Flour, graham, -	72	.29	7	4.0
Flour, bread, -	65	.67	26	12.0
Oatmeal, - -	75	.05	2	—
Rice, - - -	77	.04	—	9.0
Rye meal, - -	79	.11	3	12.0
Bread, graham, -	82	.10	2	4.0
Crackers, - -	M	.20	2	—
Sugar, - -	M	1.31	23	12.0
Molasses, - -	93	.59	10	12.0
Beans, dried, -	M	.30	10	—
Peas, green, shell'd,	15	.43	4	5.0
Potatoes, ed. port'n,	16	.26	25	13.0
Tomatoes, canned,	106	.22	3	—
Apples, dried, -	108	.16	1	10.0
Crab apples, can.,	111	.30	3	—
Cherries, fresh, -	25	.10	—	14.0
Cherries, canned,†	110	.20	1	—
Currants, fresh,†	25	1.00	15	6.0
Raspberries, fresh,	117	.40	4	4.0
Raspberries, can.,†	110	.50	2	—

* Fat estimated from the amount of the milk required to make a pound of butter.
† Com position assumed.

TABLE 37.

Weights and percentages of food materials and nutritive ingredients used in dietary of a farmer's family in Vermont. Calculated for one man 10 day.

FOOD MATERIALS.	WEIGHTS IN POUNDS.				WTS. IN GRAMS.			Cost.	Fuel Value.
	Total Wgt. Food	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.		
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Gms.	Gms.	Gms.	$	Calories
Beef,	2.3	.31	.33	—	141	147	1	.18	—
Veal,	—	—	—	—	—	—	—	—	—
Mutton,	—	—	—	—	—	—	—	—	—
Pork,	1.4	.09	.86	—	42	392	—	.16	—
Poultry,	—	—	—	—	—	—	—	—	—
Fish, etc.,	.1	.01	—	—	4	—	—	—	—
Eggs,	1.4	.19	.14	—	85	62	—	.18	—
Butter,	.7	—	.59	—	—	267	—	.14	—
Cheese,	.1	.03	.04	—	15	20	2	.02	—
Milk,	10.5	.34	.45	.52	153	206	235	.20	—
Total animal food,	16.5	.97	2.41	.52	440	1094	238	.88	12950
Vegetable Food.									
Corn meal, rye meal, and buckwheat flour,	1.8	.15	.03	1.35	69	15	614	.03	—
Wheat flours,	3.5	.41	.05	2.56	186	21	1160	.10	—
Oatmeal, rice, and wheat preparations,	.2	.04	.02	.18	16	7	83	.01	—
Bread, crackers, etc.,	.4	.04	.02	.27	19	11	122	.03	—
Sugars and starches,	3.5	.03	—	3.17	13	—	1438	.19	—
Total cereals and sugars	9.4	.67	.12	7.53	303	54	3417	.36	—
Beans and peas,	1.5	.25	.02	.68	112	10	306	.08	—
Potatoes,	2.6	.05	—	.47	25	1	215	.03	—
Other vegetables,	.3	—	—	.01	2	—	5	.02	—
Total vegetables,	4.4	.30	.02	1.16	139	11	526	.13	—
Fruit,	2.9	.03	.03	.68	13	15	307	.27	—
Total vegetable food,	16.7	1.00	.17	9.37	455	80	4250	.76	20040
Total food,	33.2	1.97	2.58	9.89	895	1174	4488	1.64	32990
Percentages Total Food.	%	%	%	%	%	%	%	%	%
Beef, veal, and mutton,	6.9	15.7	12.6	—	—	—	—	10.8	—
Pork,	4.1	4.7	33.4	—	—	—	—	9.7	—
Poultry,	—	—	—	—	—	—	—	—	—
Fish, etc.,	.1	.5	—	—	—	—	—	.3	—
Eggs,	4.3	9.5	5.2	—	—	—	—	10.9	—
Butter,	2.2	—	22.7	—	—	—	—	8.7	—
Cheese,	.4	1.7	1.7	—	—	—	—	.9	—
Milk,	31.6	17.0	17.6	5.3	—	—	—	12.5	—
Total animal food,	49.6	49.1	93.2	5.3	—	—	—	53.8	39.3
Cereals, sugars, etc.,	28.5	34.0	4.6	76.2	—	—	—	22.2	—
Vegetables,	13.3	15.5	.9	11.7	—	—	—	7.5	—
Fruits,	8.6	1.4	1.3	6.8	—	—	—	16.5	—
Total vegetable food,	50.4	50.9	6.8	94.7	—	—	—	46.2	60.7
Total food,	100.0	100.0	100.0	100.0	—	—	—	100.0	100.0

TABLE 38.

Nutrients and potential energy in food purchased, rejected, and eaten in dietary of a farmer's family in Vermont.

Food Materials.		Cost.	Nutrients. Protein.	Fat.	Carbohydrates.	Fuel Value.
For Family, 15⅓ Days.		$	Grams.	Grams.	Grams.	Calories.
Food purchased and eaten,	Animal,	8.67	4307	10724	2331	126950
	Vegetable,	—	4460	781	41644	196290
	Total, -	8.67	8767	11505	43975	323240
Per Man per Day.						
Food purchased and eaten,	Animal,	.09	44	109	24	1295
	Vegetable,	—	45	8	425	2000
	Total, -	.09	89	117	449	3295
Percentages of Total Food Purchased.		%	%	%	%	%
Food purchased and eaten,	Animal,	—	49.1	93.2	5.3	39.3
	Vegetable,	—	50.9	6.8	94.7	60.7
	Total, -	—	100.0	100.0	100.0	100.0

No. 175. DIETARY OF A MAN IN THE ADIRONDACKS IN MIDWINTER.

The study began January 25, 1896, and continued 30 days. Ninety meals were eaten, equivalent to one man 30 days. This study was carried on by a man 24 years of age, who is a consumptive and lives in the Adirondack region of Northern New York winter and summer. After boarding at hotels for several years he "determined to rent a cottage and keep house for himself." He planned to be out of doors several hours each day, though not engaged in muscular labor, and as the weather in winter was very cold, some times reaching 30° or 40° below zero Fahrenheit, this may in part account for the large amount of food eaten. The relative amount of animal food was much larger than is usually the case. The weighings of food materials were made "on a pair of reliable steelyards." The figures given represent the amounts actually eaten. None of the materials were analyzed. The data as reported by the author bore marks of much care as well as understanding of the subject.

Table 39.

Cost and weights of food materials used in dietary of a man in the Adirondacks in midwinter.

Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Reference No.	Cost.	Weight. Pounds.	Weight. Ounces.
Beef.		$					$		
Rib roast,	M	1.85	10	4.0	Rye meal,	79	.03	—	12.0
Round,	27	2.35	16	13.0	Crushed wheat,	73	.22	2	5.0
Dried and smoked,	M	.03	—	5.0	Oatmeal,	74	.09	1	—
Mutton.					Flour,	65	.04	1	13.0
Leg,	40	.96	7	8.0	Macaroni,	80	.04	—	4.0
Chops (loin),	41	.82	4	4.0	Bread,	81	.26	5	11.0
					Sugar,	M	.25	1	14.0
Fish.					Molasses,	93	.08	1	8.0
Cod, fresh,	M	.53	4	9.0	Tapioca,	M	.02	—	3.0
Cod, salt,	M	.01	—	2.0	Corn starch,	95	.04	—	3.0
Smelts,	52	.08	—	8.0	Cocoa,	M	.25	—	8.0
Salmon, canned,	53	.15	1	—	Beans,	M	.03	—	12.0
					Carrots,	99	.01	—	3.0
Eggs,	54	.42	2	3.0	Onions,	100	.11	2	4.0
Butter,	M	1.10	3	8.0	Peas,	101	.04	—	14.0
Milk,	M	3.57	99	—	Potatoes,	102	.17	34	—
					Turnips,	105	.01	—	10.0
Corn meal,	64	.05	2	8.0	Tomatoes, canned,	106	.07	1	6.0

Table 40.

Nutrients and potential energy in food purchased, rejected and eaten in dietary of a man in the Adirondacks in midwinter.

Food Materials.		Cost.	Nutrients. Protein.	Nutrients. Fat.	Nutrients. Carbo-hydrates.	Fuel Value.
For Man, 30 Days.		$	Grams.	Grams.	Grams.	Calories.
Food eaten,	Animal,	11.87	4767	6274	2252	87120
	Vegetable,	1.81	1223	216	8769	42980
	Total,	13.68	5990	6490	11021	130100
Per Man per Day.						
Food eaten,	Animal,	.40	159	209	75	2905
	Vegetable,	.06	41	7	292	1430
	Total,	.46	200	216	367	4335
Percentages of Total Food Purchased.		%	%	%	%	%
Food eaten,	Animal,	86.8	79.6	96.7	20.4	67.0
	Vegetable,	13.2	20.4	3.3	79.6	33.0
	Total,	100.0	100.0	100.0	100.0	100.0

TABLE 41.

Weights and percentages of food materials and nutritive ingredients used in dietary of a man in the Adirondacks in midwinter. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Wts. in Grams.			Cost.	Fuel Value.
	Total Weight of Food.	Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.		
	Lbs.	Lbs.	Lbs.	Lbs.	Gr.	Gr.	Gr.	$	Cal.
Animal Food.									
Beef,	9.1	1.51	1.44	—	683	654	—	1.41	—
Mutton,	3.9	.56	.78	—	254	353	—	.59	—
Fish, etc.,	2.1	.25	.04	—	115	18	2	.26	—
Eggs,	.7	.09	.07	—	43	31	—	.14	—
Butter,	1.2	—	.96	—	—	437	—	.37	—
Milk and cream,	33.0	1.09	1.32	1.65	494	598	749	1.19	—
Total animal food,	50.0	3.50	4.61	1.65	1589	2091	751	3.96	29040
Vegetable Food.									
Corn meal, rye meal, and buckwheat flour,	1.1	.09	.02	.83	42	9	373	.03	—
Wheat flours,	.6	.07	.01	.45	31	3	205	.01	—
Oatmeal, rice, and wheat preparations,	1.1	.15	.04	.80	67	17	362	.10	—
Bread, crackers, etc.,	2.0	.19	.02	1.06	86	11	482	.10	—
Sugars and starches,	1.4	.05	.05	1.14	23	22	520	.21	—
Total cereals and sugars,	6.2	.55	.14	4.28	249	62	1942	.45	—
Beans and peas,	.5	.13	.01	.33	57	3	148	.02	—
Potatoes,	11.3	.20	.01	1.73	93	5	786	.06	—
Other vegetables,	1.5	.02	—	.10	9	2	47	.07	—
Total vegetables,	13.3	.35	.02	2.16	159	10	981	.15	—
Fruit,	—	—	—	—	—	—	—	—	—
Total vegetable food,	19.5	.90	.16	6.44	408	72	2923	.60	14330
Total food,	69.5	4.40	4.77	8.09	1997	2163	3674	4.56	43370
Percentages of Total Food.	%	%	%	%	%	%	%	%	%
Beef, veal, and mutton,	18.8	46.9	46.5	—	—	—	—	43.9	—
Fish, etc.,	3.0	5.8	.8	—	—	—	—	5.6	—
Eggs,	1.0	2.2	1.5	—	—	—	—	3.1	—
Butter,	1.7	—	20.2	—	—	—	—	8.1	—
Milk,	47.4	24.7	27.7	20.4	—	—	—	26.1	—
Total animal food,	71.9	79.6	96.7	20.4	—	—	—	86.8	67.0
Cereals, sugars, etc.,	8.9	12.5	2.9	52.9	—	—	—	10.0	—
Vegetables,	19.2	7.9	.4	26.7	—	—	—	3.2	—
Total vegetable food,	28.1	20.4	3.3	79.6	—	—	—	13.2	33,0
Total food,	100.0	100.0	100.0	100.0	—	—	—	100.0	100.0

No. 176. DIETARY OF A CAMPING PARTY IN MAINE.

In the summer of 1895 four young men from 19 to 22 years of age spent some time canoeing and camping on the Allagash River, Maine. As they took their journey easily they may be considered as being engaged in light work. For part of the time they had a guide whose rations are included in the dietary. The whole time is estimated as equivalent to 115 days for one man. The following data as to the food consumption are from a record kept quite carefully by a member of the party. The weight of the fresh meat was approximate, and the composition was assumed to be that of average veal. No analysis of the food materials were made. While the estimates of quantities of nutrients lack the accuracy desirable in a dietary study they are yet of no little interest.

TABLE 42.

Weights of food materials used in dietary of a camping party in Maine.

Food Materials.	Reference No.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Reference No.	Weight. Pounds.	Weight. Ounces.
Canned corned beef,	M	12	—	Oatmeal, - -	74	2	—
Fresh meat, - -	M	100	—	Rice, - - -	77	12	—
Pork.				Hard-tack, - -	85	10	—
				Sugar, brown, -	M	35	—
Salt, fat, - -	48	24	—	Chocolate, - -	96	8	—
Bacon, - - -	47	21	—	Beans, - - -	M	15	—
Ham, - - -	M	18	—	Onions, - -	100	20	—
Lard, - - -	M	8	—	Canned peas, -	M	4	—
				Potatoes, - -	102	30	—
Canned chicken, -	51	6	—	Apples, dried, -	108	2	—
Cheese, - - -	55	1	—	*Accessories.*			
Milk, - - -	M	50	—	Coffee, - -	—	10	—
Condensed milk, -	M	5	—	Tea, - - -	—	—	8.0
Corn meal, - -	64	5	—	Baking powder, -	—	5	—
Flour, wheat, -	65	75	—	Salt, - - -	—	2	8.0

TABLE 43.

Weights and percentages of food materials and nutritive ingredients used in dietary of a camping party in Maine. Calculated for one man 10 days.

Food Materials.	Weights in Pounds.				Weights in Grams.			Fuel Value.
	Total Weight Food.	Protein.	Fat.	Carbo-hydrates.	Protein.	Fat.	Carbo-hydrates.	
Animal Food.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Grams	Grams	Cal.
Beef,	8.7	.30	.14	—	135	66	—	—
Fresh meat,	1.0	1.31	.55	—	595	249	—	—
Pork,	6.2	.41	4.17	—	188	1890	—	—
Poultry,	.5	.11	.16	—	49	71	—	—
Cheese,	.1	.02	.03	—	10	14	1	—
Milk and cream,	4.8	18	.20	.45	81	93	202	—
Total animal food,	21.3	2.33	5.25	.45	1058	2383	203	27330
Vegetable Food.								
Corn meal, rye meal, and buckwheat flour,	.5	.04	.01	.33	18	4	148	—
Wheat flour,	6.5	.73	.07	4.86	334	32	2207	—
Oatmeal, rice, and wheat preparations,	1.2	.11	.02	.94	50	8	427	—
Bread, crackers, etc.,	.9	.11	.03	.65	49	17	293	—
Sugar and starches,	3.7	.09	.33	3.08	40	149	1396	—
Total cereals, etc.,	12.8	1.08	.46	9.86	491	210	4471	—
Beans and peas,	1.3	.29	.02	.77	132	11	350	—
Potatoes,	2.6	.05	—	.40	21	1	181	—
Other vegetables,	2.1	.04	.01	.19	18	3	86	—
Total vegetables,	6.0	.38	.03	1.36	171	15	617	—
Fruits,	.2	—	.01	.10	1	2	45	—
Total vegetable food,	19.0	1.46	.50	11.32	663	227	5133	25870
Total food,	40.3	3.79	5.75	11.77	1721	2610	5336	53200
Percentages of Total Food.	%	%	%	%	%	%	%	%
Beef, veal, and mutton,	24.2	42.5	12.1	—	—	—	—	—
Pork,	15.3	10.9	72.4	—	—	—	—	—
Poultry,	1.3	2.8	2.7	—	—	—	—	—
Cheese,	.2	.6	.5	—	—	—	—	—
Milk,	11.9	4.7	3.6	3.8	—	—	—	—
Total animal food,	52.9	61.5	91.3	3.8	—	—	—	51.4
Cereals, sugars, etc.,	31.8	28.5	8.0	83.8	—	—	—	—
Vegetables,	14.9	9.9	.6	11.6	—	—	—	—
Fruits,	.4	.1	.1	.8	—	—	—	—
Total vegetable food,	47.1	38.5	8.7	96.2	—	—	—	48.6
Total food,	100.0	100.0	100.0	100.0	—	—	—	100.0

TABLE 44.

Nutrients and potential energy in food purchased, rejected and eaten in dietary of a camping party in Maine.

FOOD MATERIALS.		NUTRIENTS.			Fuel Value.
		Protein.	Fat.	Carbo-hydrates.	
For Party.		Grams.	Grams.	Grams.	Calories.
Food purchased, -	Animal, -	12169	27396	2331	314230
	Vegetable, -	7616	2625	59018	297610
	Total, -	19785	30021	61349	611840
Per Man per Day.					
Food purchased, -	Animal, -	106	238	20	2730
	Vegetable, -	66	23	513	2590
	Total, -	172	261	533	5320
Percentages of Total Food Purchased.		%	%	%	%
Food purchased, -	Animal, -	61.5	91.3	3.8	51.4
	Vegetable, -	38.5	8.7	96.2	48.6
	Total, -	100.0	100.0	100.0	100.0

SUMMARY OF THE RESULTS OF DIETARY STUDIES REPORTED BY THE STATION.

Table 45 gives a summary of the results of forty-one dietary studies reported in the present and previous Annual Reports of this Station. These are for convenience arranged into five groups: those of farmers' families, those of mechanics' families, those of the families of professional men, those of College students' clubs, and finally those which do not naturally come into either of the above classes. For the sake of comparison the average of each group is given.

The results are in all cases calculated to the same basis, "per man per day." Accordingly the figures for the College ladies' club represent larger quantities than were actually consumed. If they are multiplied by 0.8, the results will be the values "per woman per day," and will represent the amounts actually consumed in this study.

In each dietary the nutrients and fuel value, "per man per day," of the food purchased, wasted, and eaten, are shown together with the estimated digestible nutrients in the food eaten and its fuel value. These digestible nutrients were estimated by the use of the factors explained beyond.

The results of study 179, described beyond, are included in the summary table but are not in the averages.

TABLE 45.

Summary of dietary studies made by the Station.

Number.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	I.—DIETARY STUDIES AMONG FARMERS' FAMILIES.	Grams.	Grams.	Grams.	Cal.
	Two Dietaries of a Farmer's Family in Vermont.				
	Winter, 1895. (5)				
27	Food purchased and eaten, - - -	69	92	444	2960
	Estimated digestible nutrients in food eaten,	61	89	432	2850
	Summer, 1896. (6)				
174	Food purchased and eaten, - - -	89	117	449	3295
	Estimated digestible nutrients in food eaten,	81	113	438	3180
	Two Dietaries of a Farmer's Family in Connecticut.				
	December, 1894. (5)				
45	Food purchased and eaten, - - -	108	76	635	3755
	Estimated digestible nutrients in food eaten,	96	73	617	3600
	December, 1894. (6)				
46	Food purchased and eaten, - - -	109	91	608	3785
	Estimated digestible nutrients in food eaten,	97	88	592	3645
	Two Dietaries of a Farmer's Family in Connecticut.				
	Fall, 1795. (5)				
120	Food, Purchased, - - - -	114	139	545	3995
	Food, Waste, - - - - - -	14	18	44	405
	Food, Eaten, - - - - - -	100	121	501	3590
	Estimated digestible nutrients in food eaten,	92	117	486	3460
	Spring, 1896. (6)				
156	Food, Purchased, - - - -	109	206	441	4170
	Food, Waste, - - - - - -	15	29	35	475
	Food, Eaten, - - - - - -	94	177	406	3695
	Estimated digestible nutrients in food eaten,	87	171	394	3565
	Two Dietaries of a Farmer's Family in Connecticut.				
	Fall, 1895. (5)				
121	Food purchased and eaten, - - -	79	117	354	2865
	Estimated digestible nutrients in food eaten,	73	113	344	2760
	Spring, 1896. (6)				
157	Food purchased and eaten, - - -	96	139	356	3145
	Estimated digestible nutrients in food eaten,	89	134	349	3040

TABLE 45.—*(Continued.)*

Number.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	Dietary of a Farmer's Family in Connecticut (5).	Grams.	Grams.	Grams.	Cal.
123	Food, Purchased,	140	174	456	4060
	Food, Waste,	9	13	23	250
	Food, Eaten,	131	161	433	3810
	Estimated digestible nutrients in food eaten,	120	155	422	3665
	Average of Nine Dietaries as above.				
	Food, Purchased,	101	128	476	3560
	Food, Waste,	4	7	11	125
	Food, Eaten,	97	121	465	3435
	Estimated digestible nutrients in food eaten,	88	117	453	3305
	II.—DIETARY STUDIES AMONG MECHANICS' FAMILIES.				
	Dietary of a Boarding House. (1)				
1	Food, Purchased,	126	188	426	4010
	Food, Waste,	23	36	25	520
	Food, Eaten,	103	152	401	3490
	Estimated digestible nutrients in food eaten,	95	147	392	3365
	Dietary of a Blacksmith's Family. (2)				
4	Food, Purchased,	103	176	408	3730
	Food, Waste,	3	5	7	90
	Food, Eaten,	100	171	401	3640
	Estimated digestible nutrients in food eaten,	90	166	384	3485
	Dietary of a Machinist's Family. (2)				
5	Food, Purchased,	100	159	427	3640
	Food, Waste,	1	3	6	60
	Food, Eaten,	99	156	421	3580
	Estimated digestible nutrients in food eaten,	90	151	411	3460
	Two Dietaries of a Mason's Family.				
	December, 1892. (2)				
6	Food, Purchased,	107	153	429	3620
	Food, Waste,	3	5	16	120
	Food, Eaten,	104	148	413	3500
	Estimated digestible nutrients in food eaten,	97	142	402	3370
	May, 1893. (3)				
10	Food, Purchased,	125	145	366	3365
	Food, Waste,	6	8	18	175
	Food, Eaten,	119	137	348	3190
	Estimated digestible nutrients in food eaten,	113	132	339	3080

TABLE 45.—*(Continued.)*

Number.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
		Grams.	Grams.	Grams.	Cal.
	Dietary of a Carpenter's Family. (2)				
7	Food, Purchased,	125	152	498	3970
	Food, Waste,	11	17	23	300
	Food, Eaten,	114	135	475	3670
	Estimated digestible nutrients in food eaten,	106	130	463	3540
	Two Dietaries of a Carpenter's Family.				
	November, 1892. (2)				
8	Food, Purchased,	107	161	408	3610
	Food, Waste,	7	12	20	220
	Food, Eaten,	100	149	388	3390
	Estimated digestible nutrients in food eaten,	91	144	377	3260
	May, 1893. (3)				
11	Food, Purchased,	115	125	346	3055
	Food, Waste,	4	3	10	90
	Food, Eaten,	111	122	336	2965
	Estimated digestible nutrients in food eaten,	103	117	327	2850
	Dietary of a Carpenter's Family. (4)				
21	Food, Purchased,	104	118	471	3455
	Food, Waste,	3	8	1	90
	Food, Eaten,	101	110	470	3365
	Estimated digestible nutrients in food eaten,	92	106	458	3240
	Average of Nine Dietaries as above.				
	Food, Purchased,	**113**	**153**	**420**	**3605**
	Food, Waste,	**7**	**11**	**14**	**185**
	Food, Eaten,	**106**	**142**	**406**	**3420**
	Estimated digestible nutrients in food eaten,	**97**	**137**	**395**	**3295**
	III.—DIETARY STUDIES AMONG PROFESSIONAL MEN'S FAMILIES.				
	Dietary of a Chemist's Family. (1)				
2	Food purchased and eaten,	118	103	430	3210
	Estimated digestible nutrients in food eaten,	109	99	420	3090
	Dietary of a Jeweler's Family. (2)				
3	Food, Purchased,	91	126	483	3530
	Food, Waste,	8	9	5	140
	Food, Eaten,	83	117	478	3390
	Estimated digestible nutrients in food eaten,	74	111	463	3235

TABLE 45.—*(Continued.)*

Number.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	Three Dietaries of Station Agriculturist's Family.	Grams.	Grams.	Grams.	Cal.
	Winter, 1893. (3)				
9	Food, Purchased,	106	145	405	3450
	Food, Waste,	7	6	7	115
	Food, Eaten,	99	139	398	3335
	Estimated digestible nutrients in food eaten,	92	133	389	3210
	Summer, 1893. (3)				
13	Food, Purchased,	133	150	475	3885
	Food, Waste,	4	5	3	85
	Food, Eaten,	129	145	472	3800
	Estimated digestible nutrients in food eaten,	119	140	461	3680
	Fall, 1895. (6)				
169	Food, Purchased,	105	108	435	3220
	Food, Waste,	1	3	2	40
	Food, Eaten,	104	105	433	3180
	Estimated digestible nutrients in food eaten,	97	101	421	3065
	Dietary of Three Chemists. (4)				
20	Food, Purchased,	121	166	551	4300
	Food, Waste,	5	8	16	160
	Food, Eaten,	116	158	535	4140
	Estimated digestible nutrients in food eaten,	106	152	520	3980
	Three Dietaries of a Chemist's Family.				
	November, 1895. (5)				
26	Food, Purchased,	104	122	385	3140
	Food, Waste,	2	24	7	260
	Food, Eaten,	102	98	378	2880
	Estimated digestible nutrients in food eaten,	97	94	367	2775
	February, 1895. (5)				
28	Food purchased and eaten,	91	150	399	3405
	Estimated digestible nutrients in food eaten,	84	144	389	3280
	May 15, 1895. (5)				
29	Food, Purchased,	124	155	414	3650
	Food, Waste,	2	8	4	100
	Food, Eaten,	122	147	410	3550
	Estimated digestible nutrients in food eaten,	114	141	400	3420
	Average of Nine Dietaries as above.				
	Food, Purchased,	**110**	**136**	**442**	**3530**
	Food, Waste,	**3**	**7**	**5**	**100**
	Food, Eaten,	**107**	**129**	**437**	**3430**
	Estimated digestible nutrients in food eaten,	**99**	**124**	**426**	**3305**

TABLE 45.—*(Continued.)*

Number.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	IV.—DIETARY STUDIES OF STUDENTS' CLUBS.	Grams.	Grams.	Grams.	Cal.
	Dietary of a College Students' Club. (3)				
12	Food, Purchased,	113	180	376	3680
	Food, Waste,	19	39	30	570
	Food, Eaten,	94	141	346	3110
	Estimated digestible nutrients in food eaten,	87	136	338	3005
	Dietary of a College Students' Club, (4)				
16	Food, Purchased,	113	160	343	3360
	Food, Waste,	9	24	17	330
	Food, Eaten,	104	136	326	3030
	Estimated digestible nutrients in food eaten,	97	131	319	2925
	Dietary of a Divinity School Club. (4)				
17	Food, Purchased,	138	185	356	3745
	Food, Waste,	16	47	39	660
	Food, Eaten,	122	138	317	3085
	Estimated digestible nutrients in food eaten,	115	134	310	2990
	Dietary of College Ladies' Eating Club. (4)				
18	Food, Purchased,	135	196	377	3920
	Food, Waste,	30	36	47	650
	Food, Eaten,	105	160	330	3270
	Estimated digestible nutrients in food eaten,	97	154	322	3150
	Dietary of a College Students' Club. (5)				
124	Food, Purchased,	137	186	557	4575
	Food, Waste,	33	30	63	675
	Food, Eaten,	104	156	494	3900
	Estimated digestible nutrients in food eaten,	96	150	483	3770
	Average of Five Dietaries as above.				
	Food, Purchased,	**127**	**181**	**402**	**3880**
	Food, Waste,	**21**	**35**	**39**	**575**
	Food, Eaten,	**106**	**146**	**363**	**3305**
	Estimated digestible nutrients in food eaten,	**98**	**141**	**354**	**3170**
	V.—MISCELLANEOUS DIETARY STUDIES.				
	Dietary of a Widow's Family. (4)				
14	Food, Purchased,	119	115	512	3655
	Food, Waste,	3	4	12	100
	Food, Eaten,	116	111	500	3555
	Estimated digestible nutrients in food eaten,	102	107	487	3410

TABLE 45.—*(Continued.)*

Number.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	Two Dietaries of a Swede Family. (4)	Grams.	Grams.	Grams.	Cal.
	March, 1894.				
15	Food, Purchased, - - - - -	121	116	486	3565
	Food, Waste, - - - - - -	3	4	7	75
	Food, Eaten, - - - - - -	118	112	479	3490
	Estimated digestible nutrients in food eaten,	109	107	469	3365
	November, 1894.				
19	Food, Purchased, - - - - -	137	129	651	4440
	Food, Waste, - - - - - -	4	6	15	140
	Food, Eaten, - - - - - -	133	123	636	4300
	Estimated digestible nutrients in food eaten,	123	119	622	4160
	Dietary of a Family in Hartford, Conn. (6)				
23	Food, Purchased, - - - - -	87	76	510	3155
	Food, Waste, - - - - - -	—	1	1	15
	Food, Eaten, - - - - - -	87	75	509	3140
	Estimated digestible nutrients in food eaten,	77	72	498	3025
	Dietary of a Laborer's Family in Hartford, Conn. (6)				
24	Food, Purchased, - - - - -	109	102	434	3175
	Food, Waste, - - - - - -	1	2	2	30
	Food, Eaten, - - - - - -	108	100	432	3145
	Estimated digestible nutrients in food eaten,	99	96	422	3030
	Dietary of a Private Boarding House. (6)				
173	Food, Purchased, - - - - -	96	133	343	3035
	Food, Waste, - - - - - -	4	14	4	160
	Food, Eaten, - - - - - -	92	119	339	2875
	Estimated digestible nutrients in food eaten,	86	116	330	2785
	Dietary of a Man in the Adirondacks in Midwinter. (6)				
175	Food eaten, - - - - - - -	200	216	367	4335
	Estimated digestible nutrients in food eaten,	190	209	358	4190
	Dietary of a Camping Party in Maine. (6)				
176	Food purchased, - - - - - -	172	261	533	5320
	Estimated digestible nutrients in food eaten,	159	251	521	5125
	Dietary of Sandow, "the Strong Man." (7)				
179	Food eaten, - - - - - - -	244	151	502	4462

TABLE 45.—*(Continued.)*

Number.	Dietaries.		Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	Average of Nine Dietaries above, except Nos. 175, 176 and 179.		Grams.	Grams.	Grams.	Cal.
	Food,	Purchased, - - - - -	112	112	488	3500
		Waste, - - - - - -	3	5	7	90
		Eaten, - - - - - -	109	107	481	3410
	Estimated digestible nutrients in food eaten,		99	103	471	3295
	Average of 38 Dietaries above (all except Nos. 175, 176 and 179.)					
	Food,	Purchased, - - - - -	111	140	447	3595
		Waste, - - - - - -	7	11	13	185
		Eaten, - - - - - -	104	129	434	3410
	Estimated digestible nutrients in food eaten,		96	124	423	3285

(1) Report of this Station, 1891, pp. 90–106. *(2) Ibid*, 1892, pp. 135–162. *(3) Ibid*, 1893, pp. 174–190. *(4) Ibid*, 1894, pp. 174–201. *(5) Ibid*, 1895, pp. 129–170. *(6)* This Report, pp. 117–158. *(7) Ibid*, pp. 158-162.

DIETARY STUDY OF SANDOW, THE "STRONG MAN."

BY C. F. LANGWORTHY, PH. D., AND W. H. BEAL.

The information regarding the diet of professional athletes is very limited. In 1870, dietary and metabolism experiments were made with the professional pedestrian, Weston.* He walked 317½ miles in five consecutive days, covering 92 miles

* Austin Flint, Jr.: New York Medical Journal, 1871, p. 609.

NOTE.—This report of a dietary study, which is of especial interest on account of the very remarkable strength as well as the muscular activity of the subject, has been kindly furnished by the authors for publication in the present Report. The observations were made in Washington, D. C. The authors express their appreciation not only of the interest which Mr. Sandow manifested in the investigations, but also of the kindness of the proprietor of the Hotel Regent and of Harvey's restaurant, where the observations were made. They also express the hope that it may be possible at some future time to make more extended and accurate experiments, which shall include the metabolism of the food consumed. For convenience in comparing with other dietaries studied by institutions coöperating with the Department of Agriculture, this is designated as No. 179 of the series.

W. O. A.

in one day. His food consisted of beef extract, oat meal gruel, raw eggs, and a very little brandy and champagne. The diet was estimated to contain 82.5 grams of protein. During the five days immediately following the severe exercise his diet was much more abundant, including considerable meat. It was estimated to contain 181 grams of protein. The conclusion was reached that severe muscular exercise increased the metabolism of protein.

A dietary study was made of a college foot-ball team in active training at Wesleyan University in 1886.* The investigation was made toward the end of the foot-ball season, and although the exercise was vigorous, and at times severe, the members were of the opinion that they did not eat as heartily as earlier in the season. The diet contained 181 grams of protein. So far as is known, no other experiments have been made with athletes.

During an engagement of Mr. Eugen Sandow, the "strong man," in Washington, January, 1896, an attempt was made to determine the character and amount of the food he consumed. Mr. Sandow claims to be the strongest man in the world, and substantiates this claim by performing many wonderful feats of strength, one of which is the raising of a 300-pound dumb-bell above his head with one hand. He is a German by birth, and is now 29 years old; is 5 feet 9 inches tall, and weighs 200 pounds. His waist measures 28 inches; his chest, 47 inches, expanded 61 inches; upper arm, contracted 19½ inches; fore-arm, 16¼ inches; thigh, 27 inches; calf, 17½ inches; and neck, 18 inches. He states that in his youth he had no phenomenal muscular development, but acquired his present muscular condition by training. This training was begun nine years ago. At the present time he does not take regular muscular exercise other than his professional work. He has the appearance of perfect health.

Mr. Sandow does not follow any prescribed diet, but eats whatever he desires, always being careful to eat less than he craves, rather than more. He eats very slowly. He sleeps very late in the morning. Sometimes he takes a cup of weak tea and a little bread in the morning, but usually his first meal is eaten about noon. He eats again about 6 o'clock, and again

* W. O. Atwater: U. S. Dept. Agr., Office of Experiment Stations, Bulletin 21, p. 182.

about midnight, after his exhibition of feats of strength is over. He smokes a good deal, and drinks beer and other alcoholic beverages.

In the present experiment it was necessary to limit the period of observation to one day. The plan followed was to weigh each article of food as it was served to Mr. Sandow, and then weigh what was not consumed. Three meals were eaten; dinner and breakfast at the hotel where he was stopping, and supper at a restaurant. He rejected all the visible fat of the meat. No other marked peculiarity was observed.

In compiling the data obtained, the composition of the food was calculated from standard tables (Atwater's* and Konig's†). It was assumed that 1 gram of alcohol was equal to 1.71 grams of carbohydrates. The figures used are those given in table 46. The amount of food consumed at each meal, its composition, and the estimated fuel value are shown in table 47.

TABLE 46.

Estimates of composition of food materials used in computing the following dietary.

Food.	Composition. Protein.	Fat.	Carbo-hydrates.	Food.	Composition. Protein.	Fat.	Carbo-hydrates.
	%	%	%		%	%	%
Oysters,	6.2	1.2	3.7	Ice cream,	4.2	6.3	26.1
Soup (dinner),	5.2	0.9	2.8	Cake,	4.6	5.9	60.5
Celery,	1.4	0.1	3.0	Butter,	—	82.4	—
Fish,	19.2	1.0	—	Bread, rye,	10.1	0.7	55.9
Potatoes,	2.7	0.2	22.3	Cheese,	18.8	21.0	3.7
Oyster plant,	1.1	0.5	17.1	Water biscuit,	12.4	4.4	74.2
Green peas,	3.6	0.2	9.8	Beer,	0.5	—	2.7
Tomatoes,	1.2	0.2	4.0	Soup, vegetable,	2.9	—	0.5
Bread,	9.5	1.2	52.8	Veal,	20.8	9.9	—
Roast beef,	25.0	14.8	—	Bread pudding,	3.6	3.7	30.0
Chicken,	20.5	30.0	—				

* The Chemical Composition of American Food Materials (U. S. Dept. Agr., Office of Experiment Stations, Bulletin 28).

† Chemie d. menschlichen Nahrungs und Genussmittel, Vol. I.

TABLE 47.

Dietary No. 179. Food consumed in one day.

Date.	Food Consumed. (Quantities in Ounces.)	Nutrients. Protein.	Fat.	Carbo-hydrates.	Potential Energy.	Nutritive Ratio.
		Lbs.	Lbs.	Lbs.	Cal.	1:
Jan. 10. Dinner,	2 oysters, 10 soup, 1 celery, 3 fish, 1 potatoes, 2 oyster plant, 1 green peas, 1 tomatoes, 2 bread, 2 roast beef, 2½ chicken, 4 ice cream, 3 orange sherbet, ½ cakes, 1 butter, 11 wine (Burgundy),	.17	.14	.34	—	—
Supper,	8 roast beef, 7½ rye bread, 3½ Camembert cheese, 2 water biscuit, 3½ cakes, 4.4 lbs. beer,* - - -	.26	.14	.61	—	—
Jan. 11. Breakfast,†	9 vegetable soup, 2 potatoes, 3 veal (breaded chop), ½ green peas, 2 roast beef, 4½ bread pudding, ½ cakes, 14 beer, - - - -	.11	.05	.16	—	—
	Total in pounds, - -	.54	.33	1.11	4462	3.4
	Total in grams, - -	244	151	502	—	—

* Sandow sat a long time with friends after supper, and consumed a large part of the beer during this time.

† This was the regular lunch served at the hotel.

It will be seen that the heaviest meal was consumed very soon after the severe exercise. It is not claimed that the figures here given are perfectly accurate. The time of observation was very short and the diet was very varied. It would seem, however, from his own statements and from what we were able to observe, that the food of the day selected for the experiment was a fair average for Mr. Sandow's dietary habits. It is probable that the fat as computed is somewhat too high, since all the analyses of meat given in the standard tables refer to samples which contain visible fat, while, as noted above, Mr. Sandow rejected all the visible fat of the meat served him. It is, however, believed that no serious error was made in computing the composition of the food from tables rather than from analyses.

In the following table Sandow's dietary is compared with those of Weston, the foot-ball team, and the commonly accepted dietary standards for men at moderate and severe work:

TABLE 48.

Comparison of daily dietaries and dietary standards.

Subject.	Nutrients. Protein.	Fat.	Carbo-hydrates	Potential Energy.	Nutritive Ratio.
	Grams.	Grams.	Grams.	Cal.	1:
Sandow,	244	151	502	4462	3.4
Weston (walking),	83	—	—	—	—
Weston (after walking),	181	—	—	—	—
Foot-ball team per man,	181	292	557	5740	6.7
Man at moderate work (Voit),	118	56	500	3055	—
Man at moderate work (Atwater),	125	—	—	3500	5.8
Man at hard work (Voit),	145	100	450	3370	—
Man at hard work (Atwater),	150	—	—	4500	6.3

The total amount of food consumed is rather more than the average, though in his own opinion Mr. Sandow is not a large eater. This is in accord with the general conclusion reached in many investigations made with laboring men, that severe muscular exercise requires an abundant diet.

It will be seen that while the amount of carbohydrates and fat consumed does not differ very greatly from the standard for a man at muscular work, the amount of protein is very large and the nutritive ratio is very narrow.

The fact that so much protein is consumed is of especial interest. Zuntz* has advanced the opinion that the energy which is used in the production of severe muscular labor is furnished by the combustion of protein, while the energy for long continued, but not very severe, exercise is furnished by the combustion of carbohydrates or fat. The exercise performed by Mr. Sandow is very intense, and the large consumption of protein is in accord with Zuntz's theory.

* Experiment Station Record, VII., p. 538.

EXPERIMENTS ON THE DIGESTION OF FOOD BY MEN.

REPORTED BY W. O. ATWATER.

The Reports of this Station have contained accounts from time to time of digestion experiments with animals. The object of the present article is to describe the methods and results of experiments upon the digestion of different food materials by healthy men. As investigations of this particular kind are new in the United States a brief account of the purpose and plan of the experiments may be in place.*

The value of food for nutriment depends not only upon the amount of nutrients it contains, but also upon how much the body can digest and use for its support.

The question of the digestibility of food is very complex, and the current ideas regarding it are more or less indefinite and confused. One source of this confusion is the fact that what people commonly call the digestibility of food includes several very different things; some of which, as the ease with which a given food material is digested, the time required for the process, the influence of different substances and conditions upon digestion, and the effects upon comfort and health, are so dependent upon individual peculiarities of different persons, and so difficult of measurement, as to make the laying down of hard and fast rules impossible. Why it is, for instance, that some persons are made seriously ill by so wholesome a material as milk, and others find that certain kinds of meats or vegetables or sweetmeats "do not agree with them," it is difficult to explain. Late investigation, however, suggests the possibility that the ferments in the digestive canal or elsewhere may, with some people, cause particular compounds to be changed into injurious or even poisonous forms so that sometimes it may be literally true that "One man's meat is another man's poison."

* Detailed statements regarding the methods and results of inquiry in this direction may be found in Bulletin No. 21 of the Office of Experiment Stations of the United States Department of Agriculture on "Methods and Results of Investigations on the Chemistry and Economy of Food."

The digestion proper, by which we understand the changes which the food undergoes in the digestive canal in order to fit the digestible portion to be taken into the body and lymph and do its work as nutriment, is essentially a chemical process. About this a great deal has been learned within comparatively few years, although but comparatively little of the results has yet found its way into current literature.

The subject studied in the experiments here reported is a still different one. It has to do with the quantities of material actually digested from food as ordinarily eaten. The question is, What proportion of each of the nutrients in different food materials is actually digestible? In meat or bread, for instance, what percentages of the total protein, fats, and carbohydrates will be ordinarily digested by a healthy person, and what proportion of each will escape digestion?

The proportions of food constituents digested by domestic animals have been a matter of active investigation in European agricultural experiment stations during the past thirty years. During the past fifteen years not a little has been done in some stations in the United States. The experiments on digestion by sheep carried out by the Storrs Station belong to this class. The method consists in weighing and analyzing both the food consumed and the intestinal excretion. Since the latter represents very nearly the amount of food undigested, if we subtract it from the whole amount taken into the body the difference will be the amount digested.

Such experiments upon human subjects, however, are rendered much more difficult by the fact that in order that the digestibility of each particular food material may be determined with certainty, it must not be mixed with other materials. Hence the diet during the experiments must be so plain and simple as to make it extremely unpalatable. An ox will live contentedly on a diet of hay for an indefinite time, but for an ordinary man to subsist a week on meat or potatoes or eggs is a very different matter. No matter how palatable such a simple food may be, at first, to a man used to the ordinary diet of a well-to-do community, it will almost certainly become repugnant to him in a few days. In consequence, the digestive functions are disturbed and the accuracy of the trial impaired, a fact, by the way, which strikingly illustrates the importance of varied diet in civilized life.

Digestion experiments with men living on an ordinary mixed diet present no serious difficulty and it is fair to assume that the results may often be nearer approximations to the normal digestion than those of experiments with single food materials. The experiments here reported have been with single food materials and with mixed diet. Those with mixed diet are of the most consequence for the present report, not only because they apparently represent more nearly the digestibility of foods as ordinarily eaten, but because of the use made of them in a discussion in the article which follows.

In a compilation of the results of investigations of this sort made previous to 1895,* accounts were given of all the experiments which the writer and his associates found in the literature of the subject and which seemed accurate enough to be used for statistical inferences. Nearly all the experiments had been made in Europe; more had been made in Germany than in any other country. The total number of individual experiments included in the compilation was less than one hundred and fifty. Of this number 114 were with men, five with women, and 13 with children. It is evident, therefore, that the results thus far obtained are far from sufficient, and the desirability of further inquiry in this line is very clear. In connection with the investigations on the nutrition of man which are being carried out by the Department of Agriculture in Washington in coöperation with experiment stations and other institutions, quite a number of digestion experiments have already been made and others are in progress. There is reason to hope, therefore, that results of no little value will gradually accumulate.

EXPERIMENTAL METHODS FOLLOWED.

As the methods in common use for investigations of this sort have been described by the writer elsewhere,* a detailed description is hardly necessary here. It will suffice to say that in the experiments here reported the food and the feces were analyzed by the usual methods, and that the weights and composition of the materials are taken as showing the total amounts of nutrients in the food and the amounts left undigested in the feces. Subtracting the undigested residue from the total amount shows the amount actually digested.

* Bulletin 21 of the Office of Experiment Stations, pp 56–73.

This method involves two errors. One results from the imperfections of the current methods of chemical analysis, the other is due to the fact that the feces contain certain amounts of material other than undigested residue of the food—the so-called metabolic products. It is safe to assume, however, that the errors of analysis are not large. The metabolic products are mainly residues of the digestive juices, mucus, and the epithelium mechanically separated from the walls of the alimentary canal. While the quantities of these metabolic products are small they are, nevertheless, sufficient to make it desirable that allowance be made for them in accurate experimenting. No method has yet been devised for their exact determination, however, and it is customary not to take them into account but to regard them as belonging to the undigested residue of the food. As they represent material which is used for the purposes of digestion, and hence is not available to the body for the formation of tissue and the yielding of energy, this method of treating them as if they were undigested food involves practically no error so far as the value of the food for the principal purposes for which it is used, namely, to furnish the body with nourishment.

Experimenters employ various methods for distinguishing between the undigested residue of the food, the digestibility of which is being tested, and the residues from the food eaten before and after the experiment. The method here followed involves the use of milk and charcoal. For the meal immediately preceding the experiment—generally the supper of the day before the experiment begins—the subject drinks a moderate amount of milk. With this he takes a quantity of very finely divided charcoal, which is enclosed in gelatine capsules, and is easily swallowed. The feces from this milk have a consistency and color which makes it possible to separate them from those of the food which is taken for the succeeding meal. In the same way milk and charcoal are taken for the meal following the last one of the experiment. The separations by this method have proved quite satisfactory in our experience.

COEFFICIENTS OF DIGESTIBILITY.

The proportions of ingredients digested, when expressed in percentages, are commonly designated as coefficients of digestibility. Thus in experiment No. 4 (see table 49 beyond), the

subject received 463 grams of protein in the food, of which 11 grams were excreted by the intestine. This latter amount, which is here taken as representing the undigested protein, makes 2.4 per cent. of the total protein. Subtracting the 11 grams of undigested protein from the 463 grams of protein eaten, the remainder, 452 grams, makes 97.6 per cent. of the total. This is taken as the measure of the protein digested, and is thus the coefficient of digestibility of the protein in this experiment. By comparing the coefficients of digestibility, as found in a number of similar experiments, averages are obtained for general use.

Statements regarding the methods of estimating the fuel value are given on pages 177, 178.

THE DETAILS OF THE EXPERIMENTS.

The tables and descriptions which follow give accounts of fourteen individual experiments made with several different persons. The subject of Nos. 1–5 and 9–12, inclusive, was the laboratory janitor who acted as the subject of respiration experiments Nos. 1 and 2, above described. Experiment No. 6 was made with three chemists who ate together of the same food. As this experiment involves the measurement of the income and outgo of nitrogen, and was carried out with unusual care, it is treated by itself. The subject of Nos. 7 and 8 was an infant. The experiments are reported beyond by Mr. Bryant. The subjects of Nos. 13 and 14 were gentlemen engaged in experimental inquiry.

The results of experiments Nos. 1–5 and 9–14 are given in some detail in table 49. In connection with this are descriptions of the individual experiments.

TABLE 49.

DIGESTION EXPERIMENTS WITH MEN.

NOS. 1-5 AND 9-14.

Kinds, weights and composition of food materials and of undigested residues, with percentages of nutrients digested.

Food Materials.	Laboratory No.	Weight.	Percentage Composition.				Weights and Percentages Digested.				
			Protein.	Fat.	Carbohydrates.	Fuel Val. per Gram.	Organic Matter.	Protein.	Fat.	Carbohydrates.	Fuel Value.
Experiment No. 1.		Gms.	%	%	%	Cal.	Gms.	Gms.	Gms.	Gms.	Cal.
Milk, - - -	4143	4311	3.5	4.9	4.7	.842	564	151	211	202	3630
Milk, - - -	4144	2868	3.2	4.1	4.6	.767	341	91	119	131	2200
Total, - -	—	—	—	—	—	—	905	242	330	333	5830
Feces, - - -	573	118	24.3	9.0	44.1	6.003	91	29	10	52	710
Net am't digested,	—	—	—	—	—	—	814	213	320	281	4935
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	90.0	88.1	97.0	84.4	87.8
Experiment No. 2.							Gms.	Gms.	Gms.	Gms.	Cal.
Milk, - - -	4146	4756	3.8	5.5	4.2	.915	641	181	262	198	4352
Milk, - - -	4147	4741	4.0	5.7	3.9	.953	643	190	269	184	4518
Milk, - - -	4148	3165	3.5	4.3	4.1	.812	380	113	137	130	2570
Total, - -	—	—	—	—	—	—	1664	484	668	512	11440
Feces, - - -	574	201	21.9	14.9	38.4	5.732	151	44	30	77	1215
Net am't digested,	—	—	—	—	—	—	1513	440	638	435	9842
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	90.9	90.9	95.5	85.0	89.4
Experiment No. 3.							Gms.	Gms.	Gms.	Gms.	Cal.
Flour (as bread), -	575	1447	13.3	1.3	74.0	3.903	1282	193	18	1071	5648
Sugar, - - -	2722	201	—	—	100.0	3.987	201	—	—	201	801
Total, - -	—	—	—	—	—	—	1483	193	18	1272	6449
Feces, - - -	585	69	49.5	14.6	23.6	5.143	60	34	10	16	355
Net am't digested,	—	—	—	—	—	—	1423	159	8	1256	5956
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	95.9	82.3	45.4	98.7	92.4
Experiment No. 4.							Gms.	Gms.	Gms.	Gms.	Cal.
Flour (as bread), -	575	1500	13.3	1.3	74.0	3.903	1329	200	19	1110	5854
Milk, - - -	4153	3496	3.8	5.9	4.9	1.007	510	133	206	171	3520
Milk, - - -	4154	3656	3.6	6.2	4.3	1.006	514	130	227	157	3678
Total, - -	—	—	—	—	—	—	2353	463	452	1438	13052
Feces, - - -	2503	45	24.8	10.6	36.3	5.282	32	11	5	16	238
Net am't digested,	—	—	—	—	—	—	2321	452	447	1422	12421
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	98.6	97.6	98.9	98.9	95.2

DESCRIPTIONS OF INDIVIDUAL EXPERIMENTS.

Experiment No. 1.—Kind of food: Milk. *Subject:* Laboratory janitor. *Age:* 28 years. *Weight* (without clothing): 67.6 kilos (149 lbs.). The experiment commenced with breakfast, October 23, 1894, and ended with dinner, October 24, making 5 meals.

The charcoal for the separation of the feces was taken with the milk of the first meal, so that the colored feces were included in the amount collected for analysis. The second separation was made with milk and charcoal for the next meal after the end of the experiment, *i. e.*, for supper, October 24. The large weight of the feces suggests the idea that the first milk may flush the intestines so as to carry metabolic products or material with the feces which do not belong to the milk. This, if true, would account not only for the very large excretion, but also for the low digestibility of protein indicated. As a matter of fact, the excretion for the first day was very large, and for the remaining time, two-thirds of a day, very small. The subject experienced no discomfort from his diet and performed his duties about the laboratory as usual. Since the results do not appear to be entirely trustworthy, as indicating the proportions of nutrients digested, they are not included in the summary in table 53.

Experiment No. 2.—Kind of food: Milk. *Subject:* Same as in No. 1. *Weight* (without clothing): 67.6 kilos (149 lbs.). The experiment commenced with breakfast, October 29, 1894, and ended with dinner, October 31, making 8 meals. The separation of the feces was the same as in Experiment No. 1, and the same remarks apply.

Experiment No. 3.—Kind of food: Flour (as bread), and sugar. *Subject:* Same as in Nos. 1 and 2. *Weight* (without clothing): 67.6 kilos (149 lbs.). The experiment commenced with breakfast, November 6, 1894, and ended with dinner, November 8, making 8 meals. The separation of the feces was made by means of milk and charcoal taken as the last meal preceding the commencement and the first meal after the end of the experiment, *i. e.*, supper, November 5, and supper, November 8. The division was made so that none of the colored feces were included in the portion analyzed. This is the usual method of separation and was followed in all subsequent experiments. The flour was made into bread, for which 1447 grams were used, with salt and baking powder, but without fat for "shortening." The resulting bread weighed 2312 grams. This experiment is defective in that the loss of material during the process of baking is left out of account. Late experiments* indicate that the loss of fat in the baking of bread may be very considerable. For this reason, and because of the very small amount of fat present even in the uncooked flour, as well as the doubtful accuracy of fat determinations by the ordinary methods, especially in feces, the figures for the digestibility of the fat are not given.

Experiment No. 4.—Kind of food: Flour and milk. *Subject:* The same as in the preceding experiments. *Weight* (without clothing): 67.6 kilos (149 lbs.). The experiment commenced with breakfast, December 12, 1894, and ended with dinner, December 14, making 8 meals. The separation of the feces was made by milk and charcoal, as in experiment No. 3. Flour to the amount of 1500 grams was made into 2436 grams of bread, as in the preceding experiment. The statements regarding the fat in the bread apply here as in experiment No. 3, but inasmuch as the fat of the flour or bread is so small in amount as compared with that furnished by the milk, the figures for the amount of fat digested are no doubt reliable.

* See Bulletin No. 35, Office of Experiment Stations, United States Department of Agriculture, pp. 14 to 17.

TABLE 49.—*(Continued.)*

FOOD MATERIALS.	Laboratory No.	Weight.	PERCENTAGE COMPOSITION. Protein.	Fat.	Carbo-hydrates.	Fuel Val. per Gram.	WEIGHTS AND PERCENTAGES DIGESTED. Organic Matter.	Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Experiment No. 5.		Gms.	%	%	%	Cal.	Gms.	Gms.	Gms.	Gms.	Cal.
Milk, - - -	4155	4647	4.2	5.6	4.4	.977	662	198	260	204	4540
Milk, - - -	4156	4051	3.8	5.8	3.9	.913	548	154	235	159	3698
Milk, - - -	4157	4658	4.0	3.6	4.7	.778	574	186	168	220	3624
Total, - -	—	—	—	—	—	—	1784	538	663	583	11862
Feces, - - -	2504	140	17.0	9.1	43.7	5.617	98	24	13	61	826
Net am't digested,	—	—	—	—	—	—	1686	514	650	522	10589
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	94.5	95.6	98.1	89.5	89.3
Experiment No. 9.							Gms.	Gms.	Gms.	Gms.	Cal.
Bread, - -	2643	1548	8.4	.1	48.7	2.563	885	130	1	754	3968
Sugar, - -	2722	155	—	—	100.0	3.987	155	—	—	155	618
Total, - -	—	—	—	—	—	—	1040	130	1	909	4586
Feces, - - -	2644	27	38.7	16.6	21.6	5.345	21	11	4	5	144
Net am't digested,	—	—	—	—	—	—	1019	119	*	904	4338
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	98.0	91.9	—	99.4	94.6
Experiment No. 10.							Gms.	Gms.	Gms.	Gms.	Cal.
Cooked beef, round,	2681	852	23.7	16.9	—	2.910	346	202	144	—	2479
Milk, - - -	4191	3300	3.4	4.3	5.0	.836	418	114	140	164	2759
Butter, - -	4210	175	.9	88.1	—	7.973	155	1	154	—	1395
Oatmeal, - -	2682	200	17.8	7.0	66.2	4.412	182	36	14	132	882
Bread, - -	2680	1865	9.6	.2	53.9	2.813	1187	179	3	1005	5246
Sugar, - -	—	184	—	—	100.0	3.987	184	—	—	184	734
Total, - -	—	—	—	—	—	—	2472	532	455	1485	13495
Feces, - - -	2763	93	31.8	16.5	24.5	5.085	68	30	15	23	473
Net am't digested,	—	—	—	—	—	—	2404	502	440	1462	12585
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	97.3	94.4	96.7	98.5	93.3
Experiment No. 11.							Gms.	Gms.	Gms.	Gms.	Cal.
Beef, fried, - -	2696	604	29.0	9.8	1.0	2.494	240	175	59	6	1506
Eggs, boiled, -	2695	497	14.4	11.3	—	1.897	127	71	56	—	1061
Butter, - -	4238	175	.9	86.3	—	8.122	153	2	151	—	1421
Cheese, - -	4228	300	26.8	24.5	1.2	4.219	158	80	74	4	1266
Milk, - - -	4227	4400	3.6	4.2	5.4	.836	582	159	183	240	3678
Crackers, - -	2697	396	5.5	12.3	75.2	4.679	368	22	48	298	1852
Bread, - -	2693	1250	9.2	.2	50.3	2.681	746	115	2	629	3351
Potatoes, boiled, -	2694	755	2.2	.1	16.2	.787	140	17	1	122	594
Sugar, - -	2722	100	—	—	100.0	3.987	100	—	—	100	399
Total, - -	—	—	—	—	—	—	2614	641	574	1399	15128
Feces, - - -	2764	102	25.9	14.6	28.9	4.903	71	26	15	30	500
Net am't digested,	—	—	—	—	—	—	2543	615	559	1369	14093
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	97.3	95.9	97.4	97.9	93.2

* See description of experiment on opposite page.

Experiment No. 5.—Kind of food: Milk. *Subject:* The same as in the preceding experiment. *Weight* (without clothing): 67.1 kilos (148 lbs.), at the beginning, and 65.8 kilos (145 lbs.), at the end of the experiment. The experiment commenced with breakfast, December 19, 1896, and ended with supper, December 21, making 9 meals. The separation of the feces was made with milk and charcoal in the usual manner.

Experiment No. 9.—Kind of food: Bread and sugar. *Subject:* Laboratory janitor as in the preceding experiments. *Weight* (without clothing): 67.6 kilos (149 lbs.). The experiment commenced with breakfast, September 16, 1895, and ended with supper, September 17, making 6 meals. The separation of the feces was made as above, but was not as well defined as usual. The milk and charcoal feces from the supper of September 15 appeared partly on September 17 and the remainder September 18. Grape seeds from grapes eaten on the evening of September 14 were scattered through the milk and charcoal feces and a few were in the feces from the bread and sugar. To learn whether this lag in the passage of the grape seeds through the intestine was normal, grapes were eaten heartily for dinner, September 20, the seeds being swallowed. Supper consisted of milk and the following breakfast of bread. The grape seeds were scattered through the feces of the milk, of the bread and of the food next following the bread.

This experiment is practically a repetition of No. 3, except that in this instance the bread was analyzed, while in the former the flour from which the bread was made was analyzed. It will be observed that the amount of ether extract in the feces was larger than that in the bread, though the quantities in both were small. These results illustrate very forcefully the difficulty of accurate estimates of digestibility of fats by the current methods.

Experiment No. 10.—Kind of food: Mixed diet. *Subject:* Same as in the preceding experiments. *Weight* (without clothing): 67.1 kilos (148 lbs.). The experiment commenced with breakfast, January 28, 1896, and ended with dinner, January 31, making eleven meals. This experiment, with what may be called a mixed diet, represents more nearly normal conditions in this respect than any of the previous ones. The results would seem on this account to be more trustworthy as representing the digestibility of the nutrients in an ordinary diet. Accordingly the data of this experiment are used with those of Nos. 6, 11, 12, 13 and 14, which were also with mixed diet, for the computations of table 53, beyond.

Experiment No. 11.—Kind of food: Mixed diet. *Subject:* The same as in the preceding experiment. *Weight* (without clothing): 66.9 kilos (147½ lbs.). The experiment commenced with breakfast, February 15, 1896, and ended with dinner, February 19, making 14 meals, of which the last seven were taken in the respiration apparatus as respiration experiment No. 1, previously described. The cheese in the experiment was not burned in the bomb calorimeter, as the sample had decomposed before the combustion could be made. The heat of combustion was estimated from the values obtained from a similar cheese. The beef was round steak chopped fine in a meat cutter and mixed with a little onion and fried. The crackers were ordinary "milk crackers." The bread was made of rye and wheat flour and was such as the subject was accustomed to eat at home.

TABLE 49.—*(Concluded.)*

Food Materials.	Laboratory No.	Weight.	Percentage Composition.				Weights and Percentages Digested.				
			Protein.	Fat.	Carbohydrates.	Fuel Val. per Gram.	Organic Matter.	Protein.	Fat.	Carbohydrates.	Fuel Value.
Experim't No. 12.		Gms.	%	%	%	Cal.	Gms.	Gms.	Gms.	Gms.	Cal.
Beef, fried, -	2699	515	31.1	11.1	—	2.788	217	160	57	—	1436
Eggs, boiled, -	2698	498	13.6	13.0	—	2.043	133	68	65	—	1142
Butter, - -	4239	175	1.0	85.4	—	8.184	151	2	149	—	1432
Cheese, - -	4237	300	25.4	27.0	4.0	4.294	169	76	81	12	1266
Milk, - -	4240	2400	3.4	4.5	5.5	.822	321	81	108	132	1973
Crackers, - -	2701	400	10.4	12.2	69.3	4.679	368	42	49	277	1872
Rye bread, -	2703	1136	9.0	.2	49.0	2.607	661	102	2	557	2961
Potatoes, boiled,	2700	661	4.5	.1	17.5	.965	146	30	1	115	638
Sugar, - -	2722	180	—	—	100.0	3.987	180	—	—	180	718
Total, - -	—	—	—	—	—	—	2346	561	512	1273	13438
Feces, - -	2765	111	41.6	13.3	18.0	4.886	81	46	15	20	542
Net am't digested,	—	—	—	—	—	—	2265	515	497	1253	12448
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	96.6	91.8	97.1	98.4	92.6
Experim't No. 13.							Gms.	Gms.	Gms.	Gms.	Cal.
Beef, fried, -	2704	766	29.6	8.1	—	2.424	289	227	62	—	1857
Eggs, boiled, -	2705	904	22.0	17.6	—	2.937	358	199	159	—	2655
Butter, - -	4248	170	.8	88.4	—	8.435	152	2	150	—	1434
Milk, - -	4247	5380	3.3	4.5	5.5	.807	717	178	245	294	4341
Potatoes, boiled,	2708	2300	2.3	.1	21.7	1.032	554	52	3	499	2373
Bread, - -	2724	2275	8.2	1.3	50.6	2.735	1367	187	30	1150	6222
Apples, - -	2709	755	.2	.2	12.7	.547	99	2	1	96	413
Peaches, - -	2707	1400	.6	.1	9.7	.476	146	8	2	136	666
Pears, - -	2706	1400	.2	.1	19.5	.801	277	3	1	273	1121
Sugar, - -	2722	400	—	—	100.0	3.987	400	—	—	400	1595
Total, - -	—	—	—	—	—	—	4359	858	653	2848	22677
Feces, - -	2760	131	33.4	15.5	24.9	4.796	97	44	20	33	628
Net am't digested,	—	—	—	—	—	—	4262	814	633	2815	21341
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	97.8	94.9	96.9	98.9	94.1
Experim't No. 14.							Gms.	Gms.	Gms.	Gms.	Cal.
Beef, fried, -	2715	1654	34.1	10.4	—	2.904	736	564	172	—	4803
Butter, - -	4249	765	1.1	86.9	—	8.169	673	8	665	—	6249
Milk, - -	4250	10600	3.3	4.2	5.6	.798	1384	351	445	588	8459
White bread, -	2727	2550	9.2	1.4	52.8	2.892	1616	235	35	1346	7375
Brown bread, -	2726	4000	5.8	1.1	43.6	2.305	2022	232	46	1744	9220
Oatmeal, - -	2723	680	17.2	7.0	65.3	4.409	609	117	48	444	2998
Beans, - -	2728	2040	6.9	.4	18.0	1.179	516	141	7	368	2405
Potatoes, boiled,	2725	1700	2.5	.1	20.6	.989	393	42	1	350	1681
Apples, - -	2709	2125	.2	.2	12.7	.547	279	5	4	270	1162
Sugar, - -	2722	340	—	—	100.0	3.987	340	—	—	340	1356
Total, - -	—	—	—	—	—	—	8568	1695	1423	5450	45708
Feces, - -	2761	432	34.1	13.4	29.0	4.723	330	147	58	125	2049
Net am't digested,	—	—	—	—	—	—	8238	1548	1365	5325	42317
							%	%	%	%	%
Percent. digested,	—	—	—	—	—	—	96.2	91.3	95.9	97.7	96.9

Experiment No. 12.—Kind of food: Mixed diet. *Subject:* The same as in the preceding experiments. *Weight* (without clothing): 67.4 kilos (148½ lbs.). The experiment commenced with breakfast, February 24, 1896, and ended with dinner, February 28, making 14 meals, of which the last 7 were taken in the respiration calorimeter as respiration experiment No. 2, previously described. The meat was prepared as in experiment No. 11, and the diet was the same in kind, the chief difference being that only about half as much milk was taken in this experiment as in No. 11.

Experiment No. 13.—Kind of food: Mixed diet. *Subject:* Chemist, 23 years old. *Weight* (without clothing): 63.6 kilos (140 lbs.). The experiment began with breakfast, March 13, 1896, and ended with breakfast, March 21, making 25 meals, of which the last 15 were taken in the respiration calorimeter as respiration experiment No. 3. The meat was chopped and fried as in experiments 11 and 12, but without the addition of onions.

Experiment No. 14.—Subject: Physicist, 22 years old. *Weight* (without clothing): 76.2 kilos (168 lbs.). The experiment began with breakfast, March 19, 1896, and ended with dinner, April 4, making 50 meals, of which the last 36 were taken in the respiration calorimeter as respiration experiment No. 4. The meat was prepared as in the previous experiment by chopping finely with a meat chopper and then frying, the sample for analysis being taken at the same time.

DIGESTION AND METABOLISM EXPERIMENT WITH THREE CHEMISTS.

Experiment No. 6 was carried out in 1894 by Messrs. R. L. Slagle, Ph. D., H. Monmouth Smith and H. A. Torrey, chemists at that time engaged in nutrition investigations in this laboratory. The results so far as regards the consumption of food were published in the Report of the Station for 1894 (p. 194) as dietary No. 20. The object, however, was not simply to make this a dietary study, but also a digestion experiment with determinations of the income and outgo of nitrogen.

Inasmuch as part of the results of this experiment were given in the Report of the Station for 1894, as above stated, only such details are cited here as are necessary to the understanding of the investigation as an experiment upon the digestion of the food materials and the metabolism of nitrogen.

The subjects were engaged in their ordinary duties about the laboratory, and in addition to the exercise belonging to their regular work they were accustomed to walk considerable distances after their day's work was finished.

In the conduct of the experiment special care was observed. The gentlemen boarded together and sat at the same table. By the kindness of the mistress of the house, who took a very intelligent interest in the investigation, arrangements were made by which the food of the three gentlemen during the period

of the experiment was kept apart, cooked by itself and served at a separate table. One of the gentlemen was at hand to make weighings and take samples of each food material used. The securing of satisfactory samples of most of the food materials, such as bread, potatoes, milk, sugar, etc., was by no means a difficult matter. With meats, however, accurate sampling was far from easy. In order to insure accuracy in the present instance the meats were treated in a special way. Each portion was carefully separated from the bone and finely chopped. This finely chopped material was set aside, carefully preserved and cooked. A portion, however, was taken to the laboratory for analysis. Especial effort was made by this and other means to make sure that the samples of the different food materials should represent as closely as possible the food as it was actually cooked and eaten. The separations of feces were made by the method above described. The urine of each day was collected, measured, and portions were taken for the determination of the nitrogen by the Kjeldahl method. The further details are given in the descriptions which accompany the tabular statements of results.

Experiment No. 6.—Kind of food: Mixed diet. *Subject:* Three chemists, aged 23, 26 and 28 years. *Weight* (without clothing): At the beginning, 61.7, 60.3 and 68 kilos (136, 133 and 150 lbs.), and at the end, 63.5, 60.3 and 68 kilos, respectively. The experiment began with breakfast, October 10th, 1894, and ended with supper, October 19th, making 30 meals for each man.

With the exceptions noted below all the food materials were analyzed and their heats of combustion were determined by the bomb calorimeter. The fuel values of the milk and cream were not determined, but were calculated from the percentage composition by the use of the factors 5.5, 9.3 and 4.1 for the fuel values of one gram each of protein, fats and carbohydrates respectively. The crackers and apples were not analyzed, but the composition was assumed from averages of the analyses of similar food materials as given in Bulletin No. 28 of the Office of Experiment Stations of the U. S. Department of Agriculture on the "Composition of American Food Materials." The fuel values of these last named food materials were calculated by the use of the factors just referred to as employed for milk and cream. With the exception of the determinations of fuel values of the milk and cream, and the analyses and determinations of the fuel values of the crackers and apples, all of the food materials were analyzed for the purposes of the experiment and the heats of combustion were determined by the bomb calorimeter.

It should be added that the figures for protein given in the table for all the animal foods, except oysters, cheese, milk and cream, are as obtained by difference. For the animal foods just mentioned and the vegetable foods the protein is obtained by multiplying the nitrogen by the factor 6.25.

The weights and composition of the food materials and feces, and the proportions of food materials digested, are given in table 50. Table 51 gives the amounts of urine for each day and its nitrogen content, together with the weight and nitrogen content of the dried feces for the whole experiment. Table 52 shows the income and outgo of nitrogen for each day covered by the experiment, together with the estimated gain or loss of protein. The computations for these tables are made as explained in the corresponding tables in the accounts of the respiration experiments above.

TABLE 50.

DIGESTION EXPERIMENT No. 6.

Weights and composition of food materials and feces. Proportions of nutrients digested.

FOOD MATERIALS.	Laboratory No.	Percent. of Nitrogen.	Heats of Combustion per Gram.	TOTAL QUANTITIES. Weights of Materials.	Nitrogen.	Organic Matter.	Nutrients. Protein.	Fat.	Carbohydrates.	Fuel Value as Determined.
Beef.		%	Cal.	Gms.	Grams.	Gms.	Gms.	Gms.	Gms.	Cal.
Rib roast, - -	540	2.74	2.208	765	20.96	199	130	69	—	1690
Rib roast, - -	555	2.81	2.038	1035	29.08	265	177	88	—	2110
Rib roast, - -	566	2.27	2.058	565	12.83	112	74	38	—	1165
Shoulder steak, -	567	2.31	2.306	345	7.97	109	59	50	—	795
Shoulder steak, -	562	2.61	2.023	480	12.53	108	74	34	—	970
Shoulder steak, -	539	2.45	1.911	355	8.70	74	53	21	—	680
Shoulder steak, -	570	2.60	1.853	495	12.87	108	80	28	—	915
Corned, canned, -	541	4.42	3.120	470	20.77	209	132	77	—	1465
Cottolene, - -	552	—	9.561	905	—	905	—	905	—	8655
Veal rib, - -	542	2.46	1.462	865	21.28	154	132	22	—	1265
Veal rib, - -	565	2.41	1.731	640	15.42	101	79	22	—	1110
Smoked ham, -	553	2.96	3.384	355	10.51	146	67	79	—	1200
Smoked ham, -	538	2.67	2.643	270	7.21	85	46	39	—	715
Smoked ham, -	569	2.77	3.040	200	5.54	72	35	37	—	610
Salt pork, - -	561	.28	8.135	255	.71	245	5	240	—	2075
Fresh cod, - -	554	2.71	1.122	665	18.02	115	112	3	—	745
Oysters, solids, -	563	.98	.521	525	5.15	47	32	5	10	275
Eggs, - - -	568	2.06	2.019	1390	28.63	379	215	164	—	2805
Butter, - -	4145	.11	7.848	2280	2.51	1936	16	1920	—	17895
Cheese, - -	543	3.82	4.463	510	19.48	321	122	154	45	2275
Milk, - - -	4141	.53	.823	8435	44.71	1105	278	388	439	6940
Cream, - -	4142	.50	1.864	1490	7.45	344	46	250	48	2775
Corn meal, - -	545	1.41	4.033	765	10.79	693	67	12	614	3085
Flour, bread, -	549	2.14	3.968	4565	97.67	4059	612	50	3397	18105
Flour, pastry, -	550	1.86	3.945	1885	35.06	1640	219	17	1404	7435
Oat meal, - -	551	2.93	4.583	1090	31.94	998	199	79	720	4995
Macaroni, - -	544	2.30	4.076	395	9.09	350	57	4	289	1610
Milk crackers,* -	—	1.49	4.567	555	8.27	509	52	73	384	2535
Tapioca, - -	547	.05	3.718	130	.07	115	—	—	115	485
Sugar, - - -	2270	—	3.987	4255	—	4255	—	—	4255	16965
Beans, dried, -	548	3.81	4.015	695	26.48	587	165	13	409	2790
Potatoes, flesh, -	559	.38	.840	6415	24.38	1244	154	6	1084	5390
Squash, flesh, -	564	.19	.552	1760	3.34	218	21	14	183	970
Swt. potatoes, flesh,	556	.14	1.257	7555	10.58	2251	68	23	2160	9495
Turnips, flesh, -	557	.16	.304	2950	4.72	198	30	12	156	895
Apples, flesh,* -	—	.08	.755	4960	3.97	873	25	25	823	3745
Cocoanut, dried, -	546	1.04	6.982	45	.47	43	3	29	11	315
Total, - -	—	—	—	—	579.16	25172	3636	4990	16546	137945
Waste, - -	571	2.70	5.295	965	26.06	885	163	245	477	5110
Total food eaten,	—	—	—	—	553.10	24287	3473	4745	16069	132835
Feces, - - -	572	5.95	5.337	833	—	625	310	179	136	4445
Amount digested,	—	—	—	—	—	23662	3163	4566	15933	128390
Fuel value urea, -	—	—	—	—	—	—	—	—	—	2750
Net fuel value of food eaten, -	—	—	—	—	—	—	—	—	—	125640
Percent. digested,	—	—	—	—	—	97.4	91.1	96.2	99.2	94.6

* Not analyzed. Composition assumed as stated in explanation on page 174.

TABLE 51.

Weight of nitrogen in the urine of each day and the total weight of nitrogen in the feces for 10 days.

	Lab. No.	Weight of Urine.	Percent. Nitrogen.	Weight of Nitrogen.		Lab. No.	Weight of Urine.	Percent. Nitrogen.	Weight of Nitrogen.
		Gms.	%	Gms.			Gms.	%	Gms.
Urine, - -	5002	4029	1.31	52.78	Urine, - -	5010	3327	.91	30.28
Urine, - -	5003	4673	.87	40.66	Urine, - -	5011	3993	.55	21.96
Urine, - -	5004	3858	.88	33.95					
Urine, - -	5005	4549	.73	33.21	Total, - -	—	—	—	358.34
Urine, - -	5006	3695	.99	36.58	Feces, - -	572	833	5.95	49.56
Urine, - -	5007	3170	1.17	37.09					
Urine, - -	5008	3791	1.01	38.29	Total outgo of				
Urine, - -	5009	2891	1.16	33.54	urine & feces,	—	—	—	407.90

TABLE 52.

Balance of income and outgo of nitrogen in digestion experiment No. 6, with three chemists.

DATE.	INCOME.	OUTGO.				
	Nitrogen in Food.	Nitrogen in Feces.	Nitrogen in Urine.	Total.	Nitrogen Gained (+) or Lost (−).	Protein Gained (+) or Lost (−).
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
October 12, - - -	55.3	4.9	52.8	57.7	— 2.4	— 15
October 13, - - -	55.3	5.0	40.6	45.6	+ 9.7	+ 61
October 14, - - -	55.3	4.9	33.9	38.8	+16.5	+103
October 15, - - -	55.3	5.0	33.2	38.2	+17.1	+107
October 16, - - -	55.3	4.9	36.6	41.5	+13.8	+ 86
October 17, - - -	55.3	5.0	37.1	42.1	+13.2	+ 82
October 18, - - -	55.3	4.9	38.3	43.2	+12.1	+ 76
October 19, - - -	55.3	5.0	33.5	38.5	+16.8	+105
October 20, - - -	55.3	5.0	30.3	35.3	+20.0	+125
October 21, - - -	55.3	5.0	22.0	27.0	+28.3	+177
Total, - - -	553.0	49.6	358.3	407.9	+145.1	+907

It will be noticed that protein was stored constantly during the experiment, showing that the dietary furnished more of total nutrients and of nitrogenous material than was necessary for nitrogen equilibrium under the circumstances.

The amounts of food eaten varied from day to day in accordance with the inclinations of the subjects of the experiments. This doubtless explains in large part the daily variations in the nitrogen excretion.

This experiment is of interest because of the unusual care and thoroughness with which the details were carried out by the gentlemen who joined in the work; because it gives a very accurate measure of the digestibility of the nutrients of an ordinary mixed diet under normal condition, and because it adds to the list of accurate observations upon the actual food consumption of typical persons.

COMMENTS UPON THE TABLES.

Some of the data above tabulated call for a few words of explanation before we proceed to the summarizing of the results.

Fuel values.—The fuel values of the digested food may be estimated either from the heats of combustion as found by determinations with the bomb calorimeter or by the use of factors such as those of Rübner. The latter, as commonly used, apply to total rather than digestible nutrients and ascribe 4.1 calories to each gram of protein or carbohydrates and 9.3 calories to each gram of fats.

In the experiments here reported the heats of combustion of both food and feces were determined by direct combustion with oxygen in the bomb calorimeter. In experiments 11–14 inclusive the heats of combustion of the dried residue of the urine were determined in like manner.

It is hoped that a somewhat detailed discussion of the methods of estimating fuel values from the heats of combustion may be given in another place. Meanwhile it will suffice to explain briefly the methods of computation used for the preceding tables.

Net fuel value of food digested.—By subtracting the heat of combustion of the feces from that of the total food eaten we obtain the total heat of combustion of the food digested. This, however, does not represent the actual fuel value. In the first place it is not positively proved that the energy liberated and used in the body is exactly the same as that developed in the form of heat by combustion with oxygen in the calorimeter. It is common, however, to assume that such is the case. Even on this assumption the fuel value of the digested food will not be exactly the heat of combustion because not all of the digested food is completely consumed in the body. Leaving out of account the material which is either

stored in the body when the food is in excess of its demands, or consumed from the previous supply in the body when the digested food is not equal to the demands of the latter, there still remains a certain quantity of nitrogenous material which is not completely oxidized but is eliminated by the kidneys in urea and allied compounds. Assuming that all of the digested nitrogen excreted from the body is in the form of urea, we may roughly calculate the amount of the potential energy of protein which thus fails to be transformed into kinetic energy in the body.

Urea contains 46.67 per cent. N., hence N. $\times$ 2.143 = urea. N. $\times$ 6.25 = protein. Hence protein divided by 6.25 $\times$ 2.143 = the urea corresponding to the protein. The heat of combustion of one gram of urea is 2.53 calories. The fuel value of the urea corresponding to one gram of protein would therefore be 1 (gram of protein) $\div$ 6.25 $\times$ 2.143 $\times$ 2.53, or 0.87 calories.*

According to this computation, which is theoretical and but approximately correct, there would be for each gram of digested protein 0.87 calories of energy in the unconsumed urea and other compounds. Subtracting this value from the total fuel value of the digested nutrients the remainder may be assumed to represent the proportion of the total energy of the digested nutrients which becomes actually available to the body. This is designated in the tables as "net fuel value of the food digested." In estimating the coefficients of digestibility for the fuel values this net fuel value is used rather than the total fuel value of the digested nutrients.

SUMMARY OF RESULTS OF DIGESTION EXPERIMENTS.

The results of the experiments as expressed in the quantities of nutrients in the food eaten and the coefficients of digestibility are recapitulated in table 53. In this table it will be observed that experiments 1–5 and 9–12 were made with the laboratory janitor, who was used to moderately hard muscular work, while the subjects of Nos. 13 and 14 were assistants in the laboratory, whose ordinary labor involves somewhat less of muscular exercise. In experiments 11, 12, 13 and 14, however, the subjects were in the respiration apparatus and without muscular

* For further explanations of this matter see Report of this Station, 1894, pp. 125, 126.

exercise, except for a period of three days in experiment No. 14, when the muscular exercise was quite active, as explained above in the account of respiration experiment No. 4, which was part of digestion experiment No. 14. There is no reason for assuming, however, that the coefficients of digestibility of the food were materially affected by the muscular activity.

TABLE 53.

Amounts per day and percentages of nutrients digested (coefficients of digestibility) in experiments above detailed.

Number of Expt.	Subjects and Food Materials.	Protein.		Fat.		Carbo-hydrates.		Fuel Value.	
		Grams.	Per Cent.	Grams.	Per Cent.	Grams.	Per Cent.	Calories.	Per Cent.
	E. O., Laboratory Janitor.								
1	Milk, - - - - - -	128	88.1	192	97.0	168	84.4	2960	87.8
2	Milk, - - - - - -	165	90.9	239	95.5	163	85.0	3690	89.4
3	Wheat bread, - - - - -	59	82.3	(?)	(?)	471	98.7	2235	92.4
4	Bread and milk, - - -	169	97.6	168	98.9	533	98.9	4660	95.2
5	Milk, - - - - - -	171	95.6	217	98.1	174	89.5	3530	89.3
	Three Chemists.								
6	Mixed diet (see table 50), -	105	91.1	152	96.2	531	99.2	4190	94.6
	E. O., Laboratory Janitor.								
9	Wheat bread, - - - - -	60	91.9	(?)	(?)	452	99.4	2170	94.6
10	Beef round, milk, butter, oatmeal, bread, sugar, - -	137	94.4	120	96.7	399	98.5	3430	93.3
11	Beef round, eggs, butter, cheese, milk, crackers, bread, potatoes, sugar, - - -	132	95.9	120	97.4	293	97.9	3020	93.2
12	Same diet as No. 11, - -	111	91.8	107	97.1	268	98.4	2665	92.6
	O. F. T., Chemist.								
13	Beef round, eggs, butter, milk, bread, potatoes, apples, peaches, pears, sugar, -	98	94.9	76	96.9	338	98.9	2560	94.1
	A. W. S., Physicist.								
14	Beef round, butter, milk, white bread, brown bread, oatmeal, beans, potatoes, apples, sugar, - - - -	93	91.3	82	95.9	320	97.7	2540	96.9

The results of experiments 1, 2 and 3 are not entirely reliable indications of the actual digestibility of milk and bread as ordinarily eaten, partly because of defects in the experiments themselves, which were indicated above, and partly because of

the probability that these materials, taken by themselves, are not digested as completely as when they form a part of a mixed diet.

With reference to the figures of table 53, it should be observed that the results are subject to the errors inherent in experiments made by the current methods as above stated. The principal sources of error are probably three: *(a)* defects in the ordinary methods of analysis; *(b)* failure to make allowance for metabolic products, which are here considered as belonging to the undigested residue of the food, though they actually represent material which has been digested; *(c)* variations due to individuality of the subject and other influences not well understood. The error due to imperfections of analysis, while important, is probably not large. The error from treating the metabolic products in the feces as if they were a part of the undigested residue of the food, is small and of theoretical rather than practical interest so far as concerns the nutriment actually obtained from the food. The variations in digestion of the same food by different persons may be more or less considerable. As regards the variations of digestion of food by the same person under different conditions, the results of inquiry up to the present time lead to the inference that while the digestive apparatus of the subject is in normal condition, and the quantities of food are also normal, the coefficients of digestibility are much less affected by exercise or rest than is commonly supposed. There does seem to be ground, however, for the belief that in ordinary mixed diet the digestion is generally more complete than where only a single food material is eaten.

TWO DIGESTION EXPERIMENTS WITH AN INFANT.

BY A. P. BRYANT.

During the winter of 1895 two digestion experiments were made with a child nine to ten months old, in order to ascertain the amounts of nutrients consumed and digested per day with their fuel values. The first study, in February, was of eight days; the second, in March, of nine days' duration.

The subject.—The child, a boy, was a few days more than nine months old at the time of the first experiment. He was strong and healthy, weighing, at the beginning of the study, twenty-five pounds three ounces (11.43 kilos). His appetite, though at times variable, was, as a rule, hearty. He neither crept nor walked at this time. The second experiment began exactly one month later, at which time the child was learning to walk, and moved around a little by holding on to objects.

Food.—At the time of the first study the child lived entirely upon one cow's milk. During the second study a thin oatmeal gruel was mixed with the milk. This gruel was made by thinning oatmeal after cooking till, while warm, it was nearly the consistency of milk, and then passing it through a moderately fine strainer to remove lumps and coarse particles.

Each day a certain definite proportion of the milk, one cubic centimeter to the ounce (about one part in twenty-eight) was taken for analysis. These daily portions were made into a composite sample and preserved, by means of a very small amount of corrosive sublimate, until the analysis could be made. Each time the oatmeal gruel was prepared one-half was taken for analysis. The proportions of milk and oatmeal as fed in the second experiment were about four to one by volume.

Undigested residue.—In order to ascertain how much of the nutrients of the food eaten are actually absorbed, and thus utilized in the body, it is necessary to determine the amount of

undigested nutrients rejected in the feces. In digestion experiments with adults powdered charcoal can be taken at the beginning and at the end of the experimental period, as described above on page 166, and thus the exact amount of the feces which came from the food consumed during the experiment can be determined and collected for analysis. This method was impracticable in the present case, and it was assumed that the undigested residue from the food of a given day would be excreted in the feces of the following day.

Inasmuch as for some time preceding each study the daily food consumed was practically identical in kind and amount with that consumed during the experiment, any error from this assumption would probably be slight.

Composition of the food.—The food and feces were analyzed, and the heats of combustion were determined by the bomb calorimeter. The results are shown herewith.

TABLE 54.

Percentages of nutrients in the foods used in two digestion experiments with an infant, and in the feces, together with fuel values per gram as determined by the bomb calorimeter.

FOOD MATERIALS.	Lab. Number.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel Value per Gram Determined.
		%	%	%	%	%	Calories
Milk, 1st experiment,	4160	85.37	4.38	5.43	4.00	.82	.969
Milk, 2d experiment,	4162	86.20	3.94	4.47	4.62	.77	.876
Oatmeal gruel,	2535	95.69	.87	.18	2.94	.32	.188
Sugar,	2722	—	—	—	100.00	—	3.987
Feces, 1st experiment,	2519	5.14	16.38	14.08	40.39	24.01	5.915
Feces, 2d experiment,	2534	4.95	18.50	7.03	37.85	31.67	4.935

The results.—At the time of the first experiment the child was receiving milk alone. Oatmeal gruel and rice gruel had been given previously with the milk, but had for a time been discontinued. It was observed that in this experiment the milk was not thoroughly digested at all times; undigested curds frequently appeared in the feces. The child's appetite was also variable, the amount of milk taken per day varying from 33 to 50 ounces (935 to 1420 grams).

Shortly after the close of this study the child took cold and lost his appetite. This accounts for the fact that at the beginning of the second study he weighed less by over three-quarters of a pound than at the close of the first experiment.

At the time of the second experiment oatmeal gruel was added to the milk, as described above, in order to ascertain if the mixed food would be more digestible than the milk alone. This apparently was the case. The feces contained fewer undigested curds and the child's appetite was more constant. Of the protein two per cent. more was digested in the second experiment than in the first, and 1.7 per cent. more fat. The greatest difference, however, appears in the carbohydrates, where we find an increase of ten per cent. in the digestibility of the milk and oatmeal together, as compared with that of the milk alone.

DIGESTION EXPERIMENT NO. 7.

Kinds of food: Milk. *Subject:* Infant, 9 months old; weight, without clothing, 25.19 lbs. (11.43 kilos), at the beginning, and 25.38 lbs. (11.51 kilos), at the end of the experiment. *Sex:* Male. The experiment began with the first meal taken February 5, 1895, and continued 8 days, ending with the last meal taken February 12. Six meals a day were usually taken. The feces were collected from the morning of February 6 to the morning of February 14 (8 days).

TABLE 55.

Weights and fuel values of nutrients in food eaten and in feces for 8 days; and weights, fuel values, and percentages of nutrients digested.

MATERIALS.	Weight of Material.	Total Organic Matter.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value Determined.
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories
Milk (cow's), - - -	9752	1347	427	530	390	80	9450
Feces, *i. e.*, undigested residue, - - -	161	114	26	23	65	39	950
Amount digested, - -	—	1233	401	507	325	41	8500
Fuel value of urea,* -	—	—	—	—	—	—	350
Net fuel value food digested,	—	—	—	—	—	—	8150
	%	%	%	%	%	%	%
Percent. digested, - -	—	91.5	93.8	95.7	83.3	51.6	86.3

* Digested protein multiplied by .87. See explanations p. 178.

DIGESTION EXPERIMENT NO. 8.

Kinds of food: Milk, oatmeal, and sugar. *Subject:* Infant, 10 months old; same child as No. 7; weight, without clothing, 24.56 lbs. (11.14 kilos), at the beginning, and 25.60 lbs. (11.61 kilos), at the end of the experiment. The study began with the first meal eaten March 5, 1895, and continued 9 days, ending with the last meal eaten March 13. Six meals a day were usually taken. The feces were collected from the morning of March 6 to the morning of March 15 (9 days).

TABLE 56.

Weights and fuel values of nutrients in food eaten and in feces for 9 days; and weights, fuel values, and percentages of nutrients digested.

FOOD MATERIALS.	Weight of Material.	Total Organic Matter.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel Value Determined.
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Cal.
Milk (cow's), - - - -	10120	1319	399	452	468	78	8865
Oatmeal, - - - -	2722	109	24	5	80	9	505
Sugar, - - - - -	100	100	—	—	100	—	400
Total, - - - -	12942	1528	423	457	648	87	9770
Feces, *i. e.*, undigested residue, - - -	107	68	20	7	41	34	530
Amount digested, - -	—	1460	403	450	607	53	9240
Fuel value of urea,* -	—	—	—	—	—	—	350
Net fuel value food digested,	—	—	—	—	—	—	8890
	%	%	%	%	%	%	%
Percent. digested, - -	—	95.6	95.3	98.4	93.7	60.9	91.0

* Digested protein multiplied by .87. See explanations p. 178.

Nutrients and energy in daily food.—There are comparatively few statistics as to the amounts of nutrients and energy required by a child under two years of age, as compared with an older child or an adult. The following table gives the results of several dietary studies of very young children. Nos. 1 to 5 are German. No. 6 is the average of the two described above.* It will be noticed that there is no uniformity in the results. The child seven weeks old ate more than one of the children fourteen months of age.

* Published as dietary studies in the Report of this Station for 1895, p. 132.

TABLE 57.

Nutrients and energy in daily food consumed by children under 2 years of age.

Ref. No.	SUBJECT.	Protein.	Fat.	Carbo-hydrates.	Fuel Value.
		Grams.	Grams.	Grams.	Calories
1	Child, 7 weeks old, weight not given,	29	20	120	795
2	Child, 4 to 5 mos. old; weight, 5.5 kilos,	21	19	98	665
3	Child, 4 mos. old; weight, 6.6 kilos, -	8	26	63	535
4	Child, 14 mos. old; weight, 10.4 kilos, -	31	21	126	840
5	Child, 14 mos. old; weight, 6.0 kilos, -	23	22	106	735
6	Child, 8 to 9 mos. old; weight, 11.5 kilos,	50	59	62	1010*

* "As calculated" (by use of the factors 4.1 calories per gram of protein and carbohydrates, and 9.3 calories per gram of fats) for comparison with the others. By actual determination, 1090 calories.

1 and 2. Dietaries Nos. 1 and 2 are reported by Forster (Ztchr. f. Biol., 9, p. 405). The child in No. 1 was strong, healthy, and well nourished. Its parents were poor working people. No. 2 was rather sickly. Its parents were in comfortable circumstances.

3, 4, 5. Dietaries Nos. 3, 4, and 5 are reported by Camerer. No. 3, a girl, "brought up on mother's milk" (Ztchr. f. Biol., 33, 15, p. 521). No. 4, a girl (*Ibid*, 1892, p. 227). No. 5, a prematurely born child, brought up on artificial infants' foods (*Ibid*, 33, 15, p. 521).

6. The average of the digestion experiments here reported. The figures given represent food consumed, not food digested.

It has been assumed by various authorities that a child under two years of age will, on an average, require approximately from one-fourth to three-tenths as much food as an adult man. The average energy per day in the five dietaries of German children above (Nos. 1–5), is 715 calories, which is a trifle less than one-fourth of the energy of Voit's standard for a man at moderate muscular work (3050 calories). The fuel value of the food of the American child above is 1010 calories, practically three-tenths of that of the standard suggested by Atwater for a man at moderate muscular exercise (3500 calories). This value (.3) is the one used provisionally in the calculations of dietaries as explained on page 119.

It may be of interest to note here that a rough qualitative test showed but a comparatively small amount of calcium salts and of phosphoric acid in the feces while the ash of the milk and of the oatmeal contained these substances in relatively large amounts.

THE DIGESTIBILITY OF DIFFERENT CLASSES OF FOOD MATERIALS.

BY W. O. ATWATER.

In a discussion of the results of digestion experiments accompanying a compilation* prepared by the writer with the coöperation of Dr. C. Ford Langworthy, an attempt was made to summarize the results of the experiments made up to the time of the compilation (1895). The estimates for coefficients of digestibility, which were almost identical with those given on page 175 of the Report of this Station for 1892, were as follows: Animal foods: protein, 100† per cent.; fats, 95–98 per cent.; carbohydrates, 100 per cent. Vegetable foods: protein, 75–85† per cent.; fats, 95 per cent.; carbohydrates, 95 per cent.

Starting with these coefficients as a basis, food materials were divided into three general classes: 1. Animal foods, including meats, fish, eggs and dairy products. 2. Cereals and sugars, including the flours and meals from cereal grains, bakery products, starches and sugars. 3. Vegetables, including beans, peas and other leguminous seeds, and fruits. Coefficients of digestibility were assumed for the protein, fats and carbohydrates of each of the three classes. These coefficients were applied to the different classes of food materials used in some actual digestion experiment with a mixed diet. If the results obtained by the two methods, namely, by calculation and by experimental determination, agree closely, the agreement may be taken as indicating that the coefficients are approximately correct. While such a computation is not a complete mathematical demonstration, if the agreement is very close it may be regarded as sufficiently accurate for practical purposes.

* Bulletin No. 21 of the Office of Experiment Stations of the United States Department of Agriculture, On Methods and Results of Investigations on the Chemistry and Economy of Food, p. 70. The figures are practically the same as had been previously given by the writer as the outcome of a less extensive compilation, *Century Magazine*, September, 1887.

† These figures assume that the nitrogenous metabolic products of the feces belong to the digested protein.

The following figures were selected as giving very close agreement with values actually determined by experiment, and were then applied to a number of actual digestion experiments as shown in table 58 beyond. The nitrogenous metabolic products are here classed with undigested residue, thus lowering the coefficients for protein.

Assumed Coefficients of Digestibility.

	Protein.	Fat.	Carbo-hydrates.
Animal foods, - - - -	98 %	97 %	100 %
Cereals and sugars, - - -	85 %	90 %	98 %
Vegetables and fruits, - - -	80 %	90 %	95 %

To apply these figures we may take the food of a given experiment, as for instance, that of experiment No. 10, which consisted of meat, milk, butter, cheese, oatmeal and bread. In the tabular statement of details of this experiment above are shown the quantities of protein, fats and carbohydrates belonging to each food material. Assuming that 98 per cent. of the protein of the animal foods, meat, milk, butter, cheese and eggs, and that 85 per cent. of the protein of the oatmeal and bread was digested, we may calculate the amounts of protein digested from the total food eaten. Comparison of this with the total amount of protein will give the coefficient of digestibility of protein as calculated for this experiment. The computations are somewhat detailed and need not be given here. The result, however, will give a coefficient of 92.8 per cent. The coefficient as found by actual experiment was 94.4 per cent. The disparity between the two results amounts to 1.6 per cent. In the same way the coefficients for the other materials, fats and carbohydrates may be calculated and compared with those found by experiment. In table 58 such comparisons are made for experiments 6 and 10–14, above reported; that is to say, all of those in which there was a mixed diet with a considerable number of food materials. In the same table are given similar comparisons for experiments by Professor C. E. Wait, of the University of Tennessee. These experiments, which are not as yet published, belong to the series of inquiries which are being carried on at that institution in coöperation with the U. S. Department of Agriculture. It is through the courtesy of the Office of Experiment Stations that I am permitted to make use of the figures here quoted.

TABLE 58.

Coefficients of digestibility of nutrients in mixed diets. Comparisons of results of actual experiments with those obtained by calculating the digestibilities by use of the following coefficients:

	Protein.	Fat.	Carbohydrates.
Animal foods, - - - -	98 %	97 %	100 %
Cereals, etc., - - - -	85 %	90 %	98 %
Vegetables and fruits, - - -	80 %	90 %	95 %

Number.	SUBJECT.	DIET.	PROTEIN. Found by Expt.	PROTEIN. Calculated.	FAT. Found by Expt.	FAT. Calculated.	CARBOHYDRATES. Found by Expt.	CARBOHYDRATES. Calculated.
			%	%	%	%	%	%
6	Three chemists, -	Ordinary mixed diet, - -	91.1	91.3	96.2	96.5	99.2	97.2
10	Laboratory janitor, -	Meat, milk, butter, oatmeal, bread, sugar, - - -	94.4	92.8	96.6	96.7	98.5	98.2
11	Laboratory janitor, -	Meat, milk, butter, cheese, eggs, crackers, bread, sugar,	95.9	95.0	97.4	96.4	97.9	98.1
12	Laboratory janitor, -	Meat, milk, butter, cheese, eggs, crackers, bread, sugar,	91.8	93.7	97.1	96.3	98.4	98.0
13	Chemist, -	Mixed diet, - - - -	94.9	93.8	96.9	96.6	98.9	97.1
14	Physicist, -	Mixed diet, - - - -	91.3	91.5	95.9	96.3	97.7	97.7
		Avg. Nos. 6, 10, 11, 12, 13, 14,	**93.2**	**93.0**	**96.7**	**96.5**	**98.4**	**97.7**
20	Chemist, -	Bread and meat, - - -	93.2	94.9	92.0	96.0	97.4	97.8
21	Chemist, -	Bread and meat, - - -	95.4	96.0	96.3	96.3	96.9	98.0
22	Chemist, -	Bread, milk, eggs, - -	94.4	95.0	94.8	96.6	97.7	98.7
23	Chemist, -	Bread, milk, eggs, - -	95.2	95.5	93.8	96.7	96.8	98.8
24	Student, -	Bread, milk, eggs, - -	93.6	96.0	95.8	96.9	95.7	98.9
25	Chemist, -	Bread, milk, eggs, - -	96.0	94.4	94.1	93.5	97.8	98.4
		Average Nos. 20–25, - - -	**94.6**	**95.3**	**94.5**	**96.0**	**97.1**	**98.4**
26	Chemist, -	Bread, milk, beef, oatmeal, sugar, bananas, - -	92.8	93.5	96.0	96.3	97.6	97.9
27	Chemist, -	Bread, milk, beef, oatmeal, sugar, bananas, - -	92.2	91.1	91.1	96.0	98.2	98.0
28	Chemist, -	Bread, milk, beef, oatmeal, sugar, bananas, - -	93.5	95.1	95.7	96.8	97.0	98.3
		Average Nos. 26–28, - -	**92.8**	**93.2**	**94.3**	**96.4**	**97.6**	**98.1**
		Average Nos. 20–28, - -	**94.0**	**94.6**	**94.4**	**96.1**	**97.2**	**98.3**
		Average all (15), - - -	**93.7**	**94.0**	**95.3**	**96.3**	**97.7**	**98.1**

RESULTS OF EXPERIMENTS ON THE PROPORTIONS OF NUTRIENTS DIGESTED FROM FOOD MATERIALS BY HEALTHY MEN.

The results of fifteen experiments are given above, with figures showing the proportions of nutrients digested from ordinary food materials by healthy men under conditions practically normal, except that the diet was less varied than usual. In each of these experiments the coefficients of digestibility of the nutrients were found by subtracting the ingredients of the feces from those of the food, and thus obtaining the proportion digested. It seems fair

to assume that these coefficients represent fairly well the digestibility of the food materials when used in mixed diet and under such circumstances as those of these experiments.

Coefficients of digestibility were taken from the results of other experiments and slightly modified and classified for the purpose of calculation. Applying these assumed coefficients to the food materials as used in an actual experiment, the proportions of digestible nutrients for that diet are readily calculated.

The results as found by the experiments described above and those calculated by use of the assumed coefficients just referred to agree with remarkable closeness. Differences in the individual experiments range from zero to a maximum of four per cent. (in a single case), and are generally less than two per cent. In the averages of the experiments they are much smaller. The amount of this variation is shown in the following summary:

TABLE 59.

Comparison of coefficients of digestibility as found by actual experiment with those calculated as described above.

Coefficients of Digestibility.		As Found by Experiment.	As Calculated.	Calculated coefficients (+) larger, or (—) smaller, than those found by experiment.
		%	%	%
Protein,	6 experiments here reported (Nos. 6, 10–14),	91.3	91.5	+ .2
	9 experiments by Prof. Wait (Nos. 20–28),	94.0	94.6	+ .6
	Average of 15 experiments, - - - -	**93.7**	**94.0**	+ **.3**
Fats,	6 experiments here reported (Nos. 6, 10–14),	96.7	96.5	— .2
	9 experiments by Prof. Wait (Nos. 20–28),	94.4	96.1	+ 1.7
	Average of 15 experiments, - - - -	**95.3**	**96.3**	+ **1.0**
Carbohydrates,	6 experiments here reported (Nos. 6, 10–14),	98.4	97.7	— .7
	9 experiments by Prof. Wait (Nos. 20–28),	97.2	98.3	+ 1.1
	Average of 15 experiments, - - - -	**97.7**	**98.1**	+ **.4**

This close agreement implies that the assumed coefficients fairly represent the proportions of nutrients that are digested, under ordinary normal conditions, from such food materials as those used in these experiments. While they are not to be taken as an exact measure of the digestibility of every kind of food of a given class, nor, in every case as an exact measure of the average digestibility of the class as a whole, it seems probable that they do represent pretty fairly the average digestibility of these classes of food under ordinary circumstances.

THE AVERAGE COMPOSITION OF AMERICAN FOOD MATERIALS.

BY W. O. ATWATER.

The Report of this Station for 1891 contained an account of investigations upon the composition and nutritive value of food materials which had been conducted in the chemical laboratory of Wesleyan University, under the auspices of this Station and otherwise, up to that date. These included the analyses of a considerable number of specimens of American food materials. The results of these, and of similar analyses made elsewhere, were summarized in tables of the Composition of American Food Materials. Exclusive of dairy products, especially milk and butter; and sugar, molasses, sirups, etc., of which a large number of analyses had at that time been made for experimental and commercial purposes, and for inspection to prevent adulterations, the tables referred to contained results of some 400 to 500 analyses. The majority of these had been made in the writer's laboratory.

Since that time a large number of American analyses have accumulated, and a compilation of the results has been published in Bulletin 28 of the Office of Experiment Stations, U. S. Department of Agriculture.* A still later compilation has been prepared under the auspices of the Office of Experiment Stations, and now awaits publication in detail. This last includes such results as the compilers succeeded in finding up to July 1, 1896, but no attempt was made to obtain at all complete data for dairy products, sugars, etc., as above stated. The number of specimens of which analyses were included in this compilation was not far from 3,000, representing several hundred different kinds of food materials. Of these not far from 1,300 were made by the writer and his associates. Fully half of these 1,300, as well as some 900 by other chemists, have been made in connection with the food investigations now

* The Chemical Composition of American Food Materials. By W. O. Atwater and C. D. Woods.

being carried on in different parts of the country. Of the remaining 800, or thereabouts, by far the larger number were made by the Division of Chemistry of the U. S. Department of Agriculture. The extensive, varied, and important investigations upon the composition and adulterations of food materials which have been carried out by that Division, especially under the direction of Prof. H. W. Wiley, are too well known to require comment. In these statements no reference is made to the analyses of unground cereal grains, very extensive investigations of which have been made by the Division of Chemistry.

As the edition of the Bulletin of the Department of Agriculture above referred to is so limited as to make it accessible to comparatively few persons, and frequent requests come to the Station for information regarding the composition of food materials, the average composition of not far from 175 of some of the more common kinds is given in table 60. These figures are for the most part the same or nearly the same as those of the Bulletin 28 of the Office of Experiment Stations above referred to, the differences being only such as are called for by analyses which have accumulated since that Bulletin was compiled. Concerning the figures in this table, two remarks are called for:

1. The figures represent averages of analyses. Oftentimes different specimens of the same food will differ considerably in composition. This is particularly the case with meats and milk. Most kinds of vegetable foods are more nearly uniform in composition.

2. It is important to distinguish between those materials which contain more or less refuse and those which are entirely edible. In the table the designations "edible portion" and "as purchased" occur. The figures following the term "as purchased" represent the composition of the food material as ordinarily found in the markets. In the majority of foods, except dairy and cereal products, this includes more or less refuse as bone, shell, skin, or seeds. Where such inedible material, or refuse, occurs another average is given covering the composition of the "edible portion" after all refuse has been removed. Where the material as ordinarily purchased contains no refuse these terms are omitted.

TABLE 60.

Chemical composition of common food materials.

FOOD MATERIALS.		Refuse.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value per Lb.
ANIMAL FOOD. *Beef (fresh).*		%	%	%	%	%	%	Cal.
Brisket,	Edible portion,	—	54.6	16.0	28.5	—	.9	1500
	As purchased,	23.3	41.6	12.2	22.3	—	.6	1170
Chuck, lean,	Edible portion,	—	71.2	19.9	7.8	—	1.1	700
	As purchased,	23.7	54.3	15.2	6.0	—	.8	535
Chuck, medium fat,	Edible portion,	—	67.4	19.0	12.6	—	1.0	885
	As purchased,	16.8	56.1	15.8	10.5	—	.8	735
Chuck, fat,	Edible portion,	—	62.3	18.0	18.8	—	.9	1125
	As purchased,	14.7	53.3	15.4	15.9	—	.7	955
Flank,	Edible portion,	—	60.2	17.9	21.0	—	.9	1220
	As purchased,	10.2	54.0	16.1	19.0	—	.7	1100
Loin, lean,	Edible portion,	—	67.0	19.3	12.7	—	1.0	895
	As purchased,	13.1	58.2	16.7	11.1	—	.9	780
Loin, medium fat,	Edible portion,	—	60.5	18.2	20.3	—	1.0	1195
	As purchased,	13.1	52.5	15.9	17.6	—	.9	1040
Loin, fat,	Edible portion,	—	54.7	16.8	27.6	—	.9	1475
	As purchased,	10.2	49.2	15.8	24.0	—	.8	1305
Neck,	Edible portion,	—	63.4	19.2	16.5	—	.9	1055
	As purchased,	27.6	45.9	13.9	11.9	—	.7	760
Plate,	Edible portion,	—	54.4	15.7	29.1	—	.8	1520
	As purchased,	16.5	45.3	13.1	24.4	—	.7	1275
Ribs, lean,	Edible portion,	—	67.9	19.1	12.0	—	1.0	860
	As purchased,	22.6	52.6	14.8	9.3	—	.7	670
Ribs, medium fat,	Edible portion,	—	55.5	17.0	26.6	—	.9	1440
	As purchased,	20.8	43.8	13.5	21.2	—	.7	1145
Ribs, fat,	Edible portion,	—	48.1	15.4	35.8	—	.7	1795
	As purchased,	16.1	39.5	12.6	31.2	—	.6	1550
Round, lean,	Edible portion,	—	70.3	20.9	7.7	—	1.1	715
	As purchased,	8.7	64.3	19.0	7.0	—	1.0	650
Round, medium fat,	Edible portion,	—	65.5	19.8	13.6	—	1.1	940
	As purchased,	7.2	60.7	18.3	12.8	—	1.0	880
Round, second cut,	Edible portion,	—	69.8	20.5	8.6	—	1.1	745
	As purchased,	19.5	56.2	16.5	6.9	—	.9	575
Rump,	Edible portion,	—	56.2	16.8	26.1	—	.9	1415
	As purchased,	21.6	44.1	13.1	20.5	—	.7	1110
Fore shank,	Edible portion,	—	67.9	19.6	11.6	—	.9	855
	As purchased,	36.9	42.9	12.3	7.3	—	.6	535
Hind shank,	Edible portion,	—	67.8	19.8	11.5	—	.9	855
	As purchased,	53.9	31.3	9.1	5.3	—	.4	395
Shoulder and clod,*	Edible portion,	—	68.3	19.3	11.3	—	1.1	835
	As purchased,	16.4	56.8	16.1	9.8	—	.9	715
Fore quarter, lean,	Edible portion,	—	68.6	18.4	12.2	—	.8	855
	As purchased,	22.3	53.3	14.3	9.5	—	.6	665
Fore quarter, med. fat,	Edible portion,	—	60.2	17.5	21.4	—	.9	1230
	As purchased,	19.3	48.6	14.1	17.3	—	.7	990
Fore quarter, fat,	Edible portion,	—	53.5	15.8	30.0	—	.7	1560
	As purchased,	21.7	41.9	12.4	23.4	—	.6	1220
Hind quarter, lean,	Edible portion,	—	66.9	19.2	12.9	—	1.0	900
	As purchased,	16.5	55.9	16.0	10.8	—	.8	755

* As usually cut the shoulder clod has no bone, *i. e.*, refuse.

TABLE 60.—(*Continued.*)

Chemical composition of common food materials.

Food Materials.		Refuse.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value per Lb.
ANIMAL FOOD. *Beef (fresh).*		%	%	%	%	%	%	Cal.
Hind quarter, med. fat,	Edible portion,	—	60.2	17.9	21.0	—	.9	1220
	As purchased,	16.4	50.4	14.9	17.5	—	.8	1015
Hind quarter, fat, -	Edible portion,	—	52.1	16.4	30.7	—	.8	1600
	As purchased,	14.1	50.0	14.8	20.4	—	.7	1135
Side, lean, - - -	Edible portion,	—	67.2	18.7	13.2	—	.9	905
	As purchased,	19.5	54.1	15.1	10.6	—	.7	730
Side, medium fat, -	Edible portion,	—	59.7	17.5	21.9	—	.9	1250
	As purchased,	18.2	49.0	14.4	17.7	—	.7	1015
Side, fat, - - -	Edible portion,	—	47.8	15.1	36.4	—	.7	1815
	As purchased,	13.2	41.5	13.1	31.6	—	.6	1575
Liver, - - - - - -		—	71.1	20.9	5.0	1.6	1.4	630
Tallow (suet), - - - - -		—	15.0	4.8	79.9	—	.3	3460
Beef (preserved).								
Tongue, canned, - - - -		—	51.3	21.5	23.2	—	4.0	1380
Dried and smoked, - - - -		—	50.8	31.8	6.8	.6	10.0	890
Tripe, pickled, - - - - -		—	74.6	16.4	8.5	—	.5	665
Brisket, corned, - -	Edible portion,	—	50.9	18.7	24.7	—	5.7	1390
	As purchased,	21.4	40.0	14.7	19.4	—	4.5	1090
Flank, corned, - -	Edible portion,	—	49.9	14.2	33.0	—	2.9	1660
	As purchased,	12.1	43.7	12.4	29.2	—	2.6	1465
Plate, corned, - -	Edible portion,	—	40.1	13.3	41.9	—	4.7	2015
	As purchased,	14.5	34.3	11.4	35.8	—	4.0	1720
Rump, corned, - -	Edible portion,	—	58.1	15.3	23.3	—	3.3	1270
	As purchased,	6.0	54.5	14.4	22.0	—	3.1	1195
Canned, corned, - - - - -		—	53.1	28.5	14.0	—	4.4	1120
Veal (fresh).								
Chuck, - - -	Edible portion,	—	73.3	19.2	6.5	—	1.0	630
	As purchased,	18.9	59.5	15.6	5.2	—	.8	510
Cutlets, - - -	Edible portion,	—	68.3	20.8	9.9	—	1.0	805
	As purchased,	4.0	65.6	20.0	9.5	—	.9	775
Leg, - - - -	Edible portion,	—	70.4	20.1	8.4	—	1.1	730
	As purchased,	15.6	59.4	16.9	7.2	—	.9	620
Loin, - - - -	Edible portion,	—	69.2	19.4	10.4	—	1.0	800
	As purchased,	17.3	57.2	16.0	8.6	—	.9	660
Shoulder, - - -	Edible portion,	—	70.5	20.1	8.2	—	1.2	720
	As purchased,	19.5	56.8	16.2	6.5	—	1.0	575
Fore quarter, - -	Edible portion,	—	71.7	19.4	8.0	—	.9	700
	As purchased,	24.5	54.2	14.6	6.0	—	.7	525
Hind quarter, - -	Edible portion,	—	70.9	19.8	8.3	—	1.0	720
	As purchased,	20.7	56.2	15.7	6.6	—	.8	570
Side, - - - -	Edible portion,	—	71.3	19.6	8.1	—	1.0	705
	As purchased,	22.6	55.2	15.1	6.3	—	.8	545
Lamb and Mutton (fresh).								
Chuck, lean, - -	Edible portion,	—	64.7	18.1	16.3	—	.9	1025
	As purchased,	19.5	52.1	14.5	13.1	—	.8	820
Chuck, medium fat, -	Edible portion,	—	50.9	14.6	33.6	—	.9	1690
	As purchased,	21.3	39.9	11.5	26.7	—	.6	1340
Chuck, fat, - -	Edible portion,	—	40.6	13.7	44.9	—	.8	2150
	As purchased,	16.5	33.8	11.5	37.5	—	.7	1795

TABLE 60.—*(Continued.)*
Chemical composition of common food materials.

FOOD MATERIALS.		Refuse.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value per Lb.
ANIMAL FOOD.		%	%	%	%	%	%	Cal.
Lamb and Mutton (fresh).								
Leg, lean, - - -	Edible portion,	—	67.4	19.1	12.4	—	1.1	880
	As purchased,	16.8	56.1	15.9	10.3	—	.9	730
Leg, medium fat, -	Edible portion,	—	62.8	18.2	18.0	—	1.0	1100
	As purchased,	18.4	51.2	14.9	14.7	—	.8	900
Leg, fat, - - -	Edible portion,	—	55.0	17.0	27.1	—	.9	1460
	As purchased.	12.4	48.2	14.8	23.8	—	.8	1280
Loin, - - - -	Edible portion,	—	50.2	15.9	33.1	—	.8	1695
	As purchased,	16.0	42.0	13.0	28.3	—	.7	1435
Shoulder, - - - -	Edible portion,	—	61.9	17.3	19.9	—	.9	1160
	As purchased,	22.5	47.9	13.4	15.5	—	.7	905
Fore quarter, - -	Edible portion,	—	52.9	15.3	30.9	—	.9	1590
	As purchased,	21.2	41.6	12.0	24.5	—	.7	1255
Hind quarter, - -	Edible portion,	—	54.8	16.3	28.1	—	.8	1490
	As purchased,	17.2	45.4	13.5	23.2	—	.7	1230
Side, - - - -	Edible portion,	—	53.6	15.8	29.8	—	.8	1580
	As purchased,	19.3	43.3	12.7	24.0	—	.7	1275
Pork.								
Chuck, shoulder, -	Edible portion,	—	51.1	16.9	31.1	—	.9	1630
	As purchased,	18.1	41.8	13.8	25.5	—	.8	1335
Loin, lean, - -	Edible portion,	—	60.3	19.7	19.0	—	1.0	1165
	As purchased,	23.5	46.1	15.1	14.5	—	.8	895
Loin, medium fat, -	Edible portion,	—	51.1	16.7	31.3	—	.9	1630
	As purchased,	16.3	42.8	14.0	26.2	—	.7	1365
Loin, fat, - - -	Edible portion,	—	42.1	12.2	45.0	—	.7	2125
	As purchased,	14.6	35.7	10.4	38.7	—	.6	1825
Ham, fresh, - -	Edible portion,	—	44.0	13.4	41.8	—	.8	2015
	As purchased,	13.1	38.5	11.7	36.0	—	.7	1735
Ham, smoked, lean, -	Edible portion,	—	53.5	20.2	20.8	—	5.5	1255
	As purchased,	11.5	47.2	17.9	18.5	—	4.9	1115
Ham, smoked, med. fat,	Edible portion,	—	40.7	15.5	39.1	—	4.7	1940
	As purchased,	14.4	34.9	13.3	33.4	—	4.0	1655
Ham, smoked, fat, -	Edible portion,	—	27.9	16.1	52.3	—	3.7	2507
	As purchased,	3.4	25.2	14.2	53.8	—	3.4	2535
Ham, deviled, canned,	- - - -	—	45.3	18.9	32.9	—	2.9	1740
Shoulder, smoked, -	Edible portion,	—	45.0	15.8	32.5	—	6.7	1665
	As purchased,	18.2	36.8	12.9	26.6	—	5.5	1360
Salt, fat, - - -	- - - -	—	7.9	2.0	86.2	—	3.9	3675
Bacon, - - -	Edible portion,	—	17.8	9.8	68.0	—	4.4	3050
	As purchased,	8.1	16.4	8.9	62.5	—	4.1	2800
Sausage, - - -	- - - -	—	39.8	12.7	44.2	1.1	2.2	2130
Poultry.								
Chicken and fowl, -	Edible portion,	—	64.5	19.2	15.3	—	1.0	1005
	As purchased,	26.6	47.2	14.0	11.5	—	.7	745
Turkey, - - -	Edible portion,	—	55.5	20.6	22.9	—	1.0	1350
	As purchased,	22.7	42.4	15.7	18.4	—	.8	1070
Goose, - - -	Edible portion,	—	42.3	13.0	43.9	—	.8	2095
	As purchased,	22.2	33.1	10.3	33.8	—	.6	1620

TABLE 60.—*(Continued.)*

Chemical composition of common food materials.

FOOD MATERIALS.		Refuse.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value per Lb.
ANIMAL FOOD.		%	%	%	%	%	%	Cal.
Fish (fresh).								
Blue fish,	Edible portion,	—	78.5	19.0	1.2	—	1.3	405
	As purchased,	48.6	40.3	9.8	.6	—	.7	205
Cod fish,	Edible portion,	—	82.6	15.8	.4	—	1.2	310
	As purchased,	29.9	58.5	10.6	.2	—	.8	205
Cod, steaks,	Edible portion,	—	79.7	18.6	.5	—	1.2	365
	As purchased,	9.2	72.4	16.9	.5	—	1.0	335
Flounder,	Edible portion,	—	84.2	13.9	.6	—	1.3	285
	As purchased,	57.0	35.8	6.3	.3	—	.6	130
Haddock,	Edible portion,	—	81.7	16.8	.3	—	1.2	325
	As purchased,	51.0	40.0	8.2	.2	—	.6	160
Halibut steak,	Edible portion,	—	75.4	18.3	5.2	—	1.1	560
	As purchased,	17.7	61.9	15.1	4.4	—	.9	465
Mackerel,	Edible portion,	—	73.4	18 2	7.1	—	1.3	640
	As purchased,	40.7	43.7	11.4	3.5	—	.7	360
Salmon,	Edible portion,	—	65.2	20.6	12.8	—	1.4	925
	As purchased,	29.5	48.1	13.5	8.1	—	.8	590
Brook trout,	Edible portion,	—	77.8	18.9	2.1	—	1.2	440
	As purchased,	48.1	40.4	9.8	1.1	—	.6	230
Shad,	Edible portion,	—	70.6	18.6	9.5	—	1.3	745
	As purchased,	43.9	39.6	10.3	5.4	—	.8	420
Fish (preserved).								
Salt cod,	Edible portion,	—	53.6	21.4	.4	—	24.6	415
	As purchased,	24.9	40.3	16.0	.4	—	18.4	315
Boned cod,		—	54.4	22.2	.3	—	23.1	425
Smoked halibut,	Edible portion,	—	49.4	20.6	15.0	—	15.0	1015
	As purchased,	7.0	46.0	19.1	14.0	—	13.9	945
Smoked herring,	Edible portion,	—	34.6	36.4	15.8	—	13.2	1345
	As purchased,	44.4	19.2	20.2	8.8	—	7.4	745
Salt mackerel,	Edible portion,	—	42.2	22.0	22.6	—	13.2	1360
	As purchased,	22.9	32.5	17.0	17.4	—	10.2	1050
Canned salmon,		—	64.1	20.8	11.7	1.0	2.4	900
Shell Fish.								
Long clams, in shells,	Edible portion,	—	85.8	8.6	1.0	2.0	2.6	240
	As purchased,	41.9	49.9	5.0	.6	1.1	1.5	140
Round clams, in shells,	Edible portion,	—	86.2	6.5	.4	4.2	2.7	215
	As purchased,	67.5	28.0	2.1	.1	1.4	.9	70
Oysters, solids,		—	88.3	6.0	1.3	3.3	1.1	230
Lobster,	Edible portion,	—	79.2	16.4	1.8	.4	2.2	390
	As purchased,	61.7	30.7	5.9	.7	.2	.8	145
Canned lobster,		—	77.8	18.1	1.1	.5	2.5	395
Eggs,	Edible portion,	—	73.0	15.0	11.0	—	1.0	745
	As purchased,	11.2	64.8	13.3	9.8	—	.9	660
Butter,		—	—	—	*82.4	—	—	3475
Whole milk,		—	87.0	3.3	4.0	5.0	.7	325
Skimmed milk,		—	90.5	3.4	.3	5.1	.7	170
Butter milk,		—	91.0	3.0	.5	4.8	.7	165

* Average percentage of butter-fat found in the Columbian Exposition butter test.

TABLE 60.—*(Continued.)*

Chemical composition of common food materials.

Food Materials.	Refuse.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value per Lb.
Animal Food.	%	%	%	%	%	%	Cal.
Condensed milk,	—	30.5	8.2	7.1	52.3	1.9	1425
Cream,	—	74.0	2.5	18.5	4.5	.5	910
Cheese,	—	34.3	26.1	33.5	2.3	3.8	1940
Oleomargarine, butterine, etc.,	—	9.5	1.3	83.0	—	6.2	3525
Lard, cottolene, and tallow,	—	—	—	100.0	—	—	4220
Vegetable Food.							
Cereals, Sugar, Etc.							
Barley, pearled,	—	10.8	9.3	1.0	77.6	1.3	1660
Buckwheat flour,	—	14.2	5.8	1.0	78.2	.8	1605
Buckwheat, self-raising,	—	12.2	6.8	1.0	74.7	5.3	1560
Corn meal,	—	12.4	9.3	2.4	74.9	1.0	1665
Rolled oats,	—	7.2	16.6	7.2	66.9	2.1	1855
Rice,	—	12.2	7.8	.4	79.2	.4	1635
Rye flour,	—	12.9	6.8	.9	78.7	.7	1630
Graham flour,	—	11.4	13.7	2.2	70.9	1.8	1665
Entire wheat flour,	—	12.1	14.2	1.9	70.6	1.2	1660
Wheat flour,	—	12.0	11.4	1.1	75.1	.4	1655
Crushed wheat, wheatlet, farina, etc.,	—	10.4	11.4	1.7	75.7	.8	1690
Bread, white,	—	35.3	9.4	1.2	53.0	1.1	1210
Bread, rye,	—	33.5	9.9	.6	54.5	1.5	1220
Crackers, Boston,	—	8.2	10.7	9.9	68.8	2.4	1895
Crackers, milk,	—	6.1	10.5	12.5	69.1	1.8	2010
Crackers, oyster,	—	4.5	10.1	10.6	71.6	3.2	1965
Crackers, soda,	—	5.3	9.8	9.5	73.3	2.1	1945
Honey, strained,	—	18.0	.3	—	81.5	.2	1520
Molasses,	—	25.1	2.4	—	69.3	3.2	1335
Sugar, granulated,	—	—	—	—	100.0	—	1860
Sugar, brown,	—	—	—	—	95.0	—	1765
Maple sugar,	—	—	—	—	82.8	—	1540
Maple syrup,	—	—	—	—	70.1	—	1305
Starch,	—	6.0	—	—	93.8	.2	1745
Tapioca,	—	11.6	.4	.3	87.5	.2	1650
Vegetable.							
Beans, dry,	—	13.1	22.4	1.8	59.1	3.6	1590
Beans, green, shelled,	—	58.9	9.4	.6	29.1	2.0	740
Beans, string,	—	87.7	2.3	.3	8.9	.8	220
Beans, lima, green,	—	68.5	7.1	.7	22.0	1.7	570
Beets, { Edible portion,	—	87.5	1.5	.1	9.8	1.1	215
Beets, { As purchased,	20.0	70.0	1.2	.1	7.8	.9	170
Cabbage, { Edible portion,	—	90.9	1.9	.3	5.7	1.2	155
Cabbage, { As purchased,	15.0	77.3	1.6	.3	4.8	1.0	130
Carrots, { Edible portion,	—	88.3	1.1	.3	9.2	1.1	205
Carrots, { As purchased,	20.0	70.7	1.0	.2	7.2	.9	160
Cauliflower,	—	90.8	1.6	.8	6.0	.8	175
Celery,	—	93.7	1.3	.1	3.8	1.1	100
Sweet corn, green, { Edible portion,	—	75.4	3.1	1.1	19.7	.7	470
Sweet corn, green, { As purchased,	60.0	30.2	1.2	.4	7.9	.3	185

TABLE 60.—*(Continued.)*

Chemical composition of common food materials.

Food Materials.		Refuse.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel Value per Lb.
VEGETABLE FOOD.		%	%	%	%	%	%	Cal.
Vegetable.								
Cucumbers,	Edible portion,	—	95.4	.8	.2	3.1	.5	80
	As purchased,	15.0	81.1	.7	.2	2.6	.4	70
Lettuce,	Edible portion,	—	94.0	1.3	.4	3.3	1.0	105
	As purchased,	18.0	77.1	1.1	.3	2.7	.8	85
Onions,	Edible portion,	—	87.1	1.7	.4	10.2	.6	240
	As purchased,	10.0	78.4	1.5	.4	9.2	.5	215
Parsnips,	Edible portion,	—	83.0	1.6	.5	13.5	1.4	300
	As purchased,	20.0	66.4	1.3	.4	10.8	1.1	240
Peas, dry,	- - -	—	9.5	24.6	1.0	62.0	2.9	1655
Peas, green,	Edible portion,	—	74.1	6.6	.4	17.9	1.0	470
	As purchased,	50.0	37.1	3.3	.2	8.9	.5	235
Potatoes,	Edible portion,	—	78.0	2.2	.1	18.8	.9	395
	As purchased,	15.0	66.3	1.9	.1	16.0	.7	335
Pumpkins,	Edible portion,	—	93.1	1.0	.1	5.2	.6	120
	As purchased,	50.0	46.6	.5	—	2.6	.3	60
Radishes,	Edible portion,	—	91.8	1.3	.1	5.8	1.0	135
	As purchased,	30.0	64.2	.9	.1	4.1	.7	100
Rhubarb,	Edible portion,	—	94.4	.6	.7	3.6	.7	105
	As purchased,	40.0	56.6	.4	.4	2.2	.4	65
Squash,	Edible portion,	—	88.3	1.4	.5	9.0	.8	215
	As purchased,	50.0	44.2	.7	.2	4.5	.4	105
Sweet potatoes,	Edible portion,	—	69.0	1.8	.7	27.4	1.1	565
	As purchased,	15.0	58.7	1.5	.6	23.3	.9	485
Tomatoes,	- - -	—	94.3	.9	.4	3.9	.5	109
Turnips,	Edible portion,	—	89.6	1.3	.2	8.1	.8	185
	As purchased,	30.0	62.7	.9	.1	5.7	.6	125
Vegetables (canned).								
Beans, baked,		—	68.4	6.9	3.1	19.6	2.0	625
Beans, string,		—	93.7	1.1	.1	3.7	1.4	95
Peas, green,		—	85.3	3.6	.2	9.8	1.1	255
Sweet corn,		—	75.7	2.8	1.3	19.3	.9	465
Squash,		—	87.6	.9	.5	10.5	.5	235
Succotash,		—	75.9	3.6	.9	18.7	.9	455
Tomatoes,		—	94.3	1.1	.2	3.8	.6	100
Fruit (fresh).								
Apples,	Edible portion,	—	83.5	.4	.5	15.2	.4	310
	As purchased,	25.0	62.6	.3	.4	11.4	.3	235
Bananas,	Edible portion,	—	75.2	1.2	.7	22.0	.9	460
	As purchased,	40.0	45.1	.7	.4	13.2	.6	275
Cherries,	Edible portion,	—	86.1	1.1	.8	11.4	.6	265
Cranberries,	- - -	—	88.9	.4	.6	9.9	.2	215
Grapes,	Edible portion,	—	77.4	1.3	1.6	19.2	.5	450
	As purchased,	25.0	58.0	1.0	1.2	14.4	.4	335
Oranges,	Edible portion,	—	88.3	.8	.6	9.7	.6	220
	As purchased,	27.0	64.5	.6	.4	7.1	.4	160
Strawberries,	Edible portion,	—	90.4	1.0	.7	7.3	.6	185
	As purchased,	10.0	81.4	.9	.6	6.6	.5	165

TABLE 60.—*(Concluded.)*

Chemical composition of common food materials.

Food Materials.		Refuse.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel Value per Lb.
VEGETABLE FOOD.		%	%	%	%	%	%	Cal.
Fruit (preserved).								
Apples, dried, evaporated,		—	29.3	1.7	2.3	64.9	1.8	1335
Dates,	Edible portion,	—	15.4	2.1	2.8	78.4	1.3	1615
	As purchased,	9.8	13.8	1.9	2.5	70.8	1.2	1455
Prunes, dried,	Edible portion,	—	24.8	2.9	1.5	68.8	2.0	1395
	As purchased,	15.0	21.1	2.4	1.3	58.5	1.7	1190
Raisins,		—	14.6	2.6	3.3	76.1	3.4	1605
Apricots, dried,		—	32.4	2.9	*	63.3	1.4	1230
Peaches, canned,		—	91.5	.5	.2	7.5	.3	155
Nuts.								
Chestnuts, fresh,	Edible portion,	—	38.5	6.9	8.0	44.9	1.7	1300
	As purchased,	16.0	32.4	5.8	6.7	37.7	1.4	1090
Peanuts,	Edible portion,	—	9.2	25.8	38.6	24.4	2.0	2560
	As purchased,	33.0	6.2	17.3	25.9	16.3	1.3	1720
Beverages.								
Cocoa,		—	4.6	21.6	28.9	37.7	7.2	2320
Chocolate,		—	5.9	12.9	48.7	30.3	2.2	2860

*Fat not determined.

PROPORTIONS OF DIGESTIBLE NUTRIENTS IN FOOD MATERIALS.

BY W. O. ATWATER.

In all of the statements concerning the composition of food materials and estimates of the proportions of nutrients in dietaries and dietary standards published by the Station before the present Report, the total rather than the digestible nutrients have been considered. This usage has been followed in the publications of the Office of Experiment Stations, and by writers and teachers generally. The reason for not making the statements and calculations in terms of digestible nutrients has been a very simple one. The data regarding the digestibility of food materials as they are ordinarily eaten have been hardly sufficient to warrant going beyond the use of the total nutrients. The usage of chemists and physiologists in Europe has been practically the same as in this country, and for the same reason.

Tentative efforts have, nevertheless, been made toward the putting of the estimates of the nutritive values of foods and the standards for dietaries upon the basis of digestible nutrients. Thus Voit,* in 1882, using the results of Rübner's experiments on the digestion of food materials by men, has estimated the quantities of digestible nutrients corresponding to the total nutrients in his well-known standard for the daily dietary of an average man at moderate muscular work. His figures, as modified by König in 1889,† are:

	Protein.	*Fat.*	*Carbo-hydrates.*
Total, - - - - - - -	118	56	500
Digestible, - - - - - -	106	53	450

In like manner Von Rechendorff, in studies of dietaries of hand weavers in Zittau, Saxony, published in 1890,‡ has made detailed calculations of the proportions of both total and

* "Physiologie des Allgemeinen Stoffwechsels und der Ernährung."

† "Chemie der menschlichen Nahrungs und Genussmittel." Third edition, I., 154.

‡ Bulletin No. 21, Office of Experiment Stations, United States Department of Agriculture, On Methods and Results of Investigations with Chemistry and Economy of Food, p. 163.

digestible nutrients in a considerable number of dietaries. Similar attempts have been made by the writer from time to time.*

It has been the custom of both American and European chemists and physiologists, for a number of years, to make use of the figures for digestible nutrients in estimating the nutritive values of feeding stuffs and in calculating the rations for domestic animals. This has seemed to be warranted by the number of experiments in which the digestibility of feeding stuffs has been determined by actual tests.

The tests of the digestibility of food by man reported up to the present time are much less numerous than those of feeding stuffs by domestic animals, at the same time the variety of materials in common use, as food of man, is much larger than that of feeding stuffs for animals. It would thus seem, at first thought, that while the data may be sufficient for the setting up of coefficients of digestibility of feeding stuffs and basing calculations upon them, the information thus far accumulated is still too small to warrant us in applying the same principle to food materials.

There are, however, some considerations in favor of the use of the coefficients of digestibility for the food of man. In the first place our ordinary food materials are so much more easily and completely digestible than feeding stuffs that the undigested residue of food as used in ordinary diet under normal conditions by men, women, and children make a much smaller proportion of the whole than is the case with feeding stuffs as eaten by domestic animals. The variations in digestibility are likewise much less with the food of man. Indeed, this is specially the case with animal foods and with the carbohydrates which are the principal constituents in most vegetable foods. The variations in the digestibility of protein in the vegetable foods are somewhat wider. The determinations of the digestibility of fats of most vegetable foods, by the methods commonly followed, bring very uncertain coefficients of digestibility, because of the very small quantities of fats. The errors here, however, are of less practical consequence, because the fats of the vegetable foods make so small a proportion of the total diet.

One great difficulty with the larger number of digestion experiments hitherto made with man is found in the fact

* Bulletin 21, Office of Experiment Stations, p. 71. See also, *Century Magazine*, September, 1887.

referred to in the discussion of the subject of coefficients of digestibility in the preceding article, viz., that they have been made with single food materials, and the indications are that the digestion is less complete in these cases than it would be with ordinary mixed diet. In the article just referred to, the attempt was made to find coefficients of digestibility for the nutrients of different classes of food materials such as would, when applied to the constituents of ordinary mixed diet, give estimates for the quantities of digestible nutrients corresponding to the results of actual experiment with the same diet. From the data which had accumulated up to the present time coefficients of digestibility were assumed for the nutrients in different classes of foods, as explained on page 187. These coefficients were afterwards applied to a series of actual digestion experiments, and the proportion of estimated digestible nutrients obtained by their use was found to agree almost exactly with those obtained by actual experiment. The differences, indeed, were in most cases hardly wider than are often found in duplicate analyses of the same specimen of a given food material, by different chemists following the same analytical methods. Such coincidences were observed in a considerable number of cases. And it would appear that they could be hardly possible unless the assumed coefficients were tolerably close approximations to the truth. It seems safe, therefore, to use these coefficients for tentative estimates for the digestibility of some of the more common food materials. This is done in table 61. With reference to the computations, however, two things should be clearly understood:

First.—The estimates are only tentative and are subject to revision as information accumulates regarding both the composition and digestibility of the food materials. It is worth noting, however, that the probable errors in the figures assumed for the coefficients are apparently less than the known variations in the composition of different specimens of food materials of the same kind.

Second.—Some further distinctions need to be made between the coefficients of digestibility of different materials of the same general group. For instance, ordinary wheat flour, so-called "entire wheat flour" or "whole wheat," and graham flour

differ considerably in digestibility. But experimental data at hand are not sufficient to show what these differences are. Experiments upon this subject are now being carried on, however, under the auspices of the Office of Experiment Stations, and it is hoped that the needed information may be gradually acquired.

Fuel values.—In the following table the fuel values of the digested nutrients were calculated by the use of the factors proposed by Rübner and now ordinarily accepted as explained on page 177. The factor 4.1 as used for the fuel value of one gram of protein is evidently too small. Indeed, all the factors need revision to fit them to different food materials and conditions of use. It is hoped that results of investigations upon the subject now in progress in this laboratory may be published in the near future. Meanwhile the common factors are used in these calculations, but with the understanding that they will doubtless be changed later.

Table 61.

Estimates of proportions of digestible and undigestible nutrients in food materials. In these calculations it is assumed that the following percentages are digestible:

	Protein.	*Fat.*	*Carbohydrates.*	*Mineral Matters.*
Animal foods, - - - -	98 %	97 %	100 %	75 %
Cereals and sugars, - - -	85 %	90 %	98 %	75 %
Vegetables and fruits, - -	80 %	90 %	95 %	75 %

Food Materials.		Refuse.	Edible Portion. Water.	Nutrients. Digestible. Protein.	Digestible. Fat.	Digestible. Carbohydrates.	Digestible. Mineral Matters.	Undigestible.	Fuel Value of Digestible Nutrients.
Animal Food.		%	%	%	%	%	%	%	Cal.
Beef.									
Chuck, - - -	Edible portion,	—	67.4	18.6	12.2	—	.7	1.1	860
	As purchased,	16.8	56.1	15.5	10.2	—	.6	.8	715
Loin, - - -	Edible portion,	—	60.5	17.8	19.7	—	.8	1.2	1165
	As purchased,	13.1	52.5	15.6	17.1	—	.7	1.0	1010
Neck, - - -	Edible portion,	—	63.4	18.8	16.0	—	.7	1.1	1025
	As purchased,	27.6	45.9	13.6	11.5	—	.5	.9	740
Ribs, - - -	Edible portion,	—	55.5	16.7	25.8	—	.7	1.3	1400
	As purchased,	20.8	43.8	13.2	20.6	—	.5	1.1	1115
Round, - - -	Edible portion,	—	65.5	19.4	13.2	—	.8	1.1	915
	As purchased,	7.2	60.7	17.9	12.4	—	.8	1.0	855

TABLE 61.—*(Continued.)*

Food Materials.		Refuse.	Edible Portion.						Fuel Value of Digestible Nutrients.
			Water.	Nutrients.					
				Digestible.				Undigestible.	
				Protein.	Fat.	Carbo-hydrates.	Mineral Matters.		
ANIMAL FOOD.		%	%	%	%	%	%	%	Cal.
Beef.									
Rump,	Edible portion,	—	56.2	16.5	25.3	—	.7	1.3	1375
	As purchased,	21.6	44.1	12.8	19.9	—	.5	1.1	1080
Shank,	Edible portion,	—	67.8	19.4	11.2	—	.7	.9	835
	As purchased,	53.9	31.3	8.9	5.1	—	.3	.5	380
Shoulder,	Edible portion,	—	68.3	18.9	11.0	—	.8	1.0	815
	As purchased,	16.4	56.8	15.8	9.5	—	.7	.8	695
Fore quarter,	Edible portion,	—	60.2	17.2	20.8	—	.7	1.1	1200
	As purchased,	19.3	48.6	13.8	16.8	—	.5	1.0	965
Hind quarter,	Edible portion,	—	60.2	17.5	20.4	—	.7	1.2	1190
	As purchased,	16.4	50.4	14.6	17.0	—	.6	1.0	990
Liver,		—	71.1	20.5	4.9	1.6	1.1	.8	620
Corned, canned,		—	53.1	27.9	13.6	—	3.3	2.1	1090
Corned,	Edible portion,	—	54.5	15.3	24.7	—	3.3	2.2	1325
	As purchased,	9.4	49.6	13.9	22.1	—	3.0	2.0	1190
Dried, smoked,		—	50.8	31.8	6.8	.6	7.5	2.5	860
Veal.									
Chuck,	Edible portion,	—	73.3	18.8	6.3	—	.8	.8	615
	As purchased,	18.9	59.5	15.3	5.0	—	.6	.7	495
Cutlets,	Edible portion,	—	68.3	20.4	9.6	—	.8	.9	785
	As purchased,	4.0	65.6	19.6	9.2	—	.7	.9	755
Loin,	Edible portion,	—	69.2	19.0	10.1	—	.8	.9	780
	As purchased,	17.3	57.2	15.7	8.3	—	.7	.8	640
Shoulder,	Edible portion,	—	70.5	19.7	8.0	—	.8	1.0	705
	As purchased,	19.5	56.8	15.9	6.3	—	.8	.7	560
Side,	Edible portion,	—	71.3	19.2	7.9	—	.8	.8	690
	As purchased,	22.6	55.2	14.8	6.1	—	.6	.7	535
Mutton.									
Leg,	Edible portion,	—	62.8	17.8	17.5	—	.8	1.1	1070
	As purchased,	18.4	51.2	14.6	14.3	—	.6	.9	875
Loin,	Edible portion,	—	50.2	15.6	32.1	—	.6	1.5	1645
	As purchased,	16.0	42.0	12.7	27.5	—	.5	1.3	1395
Shoulder,	Edible portion,	—	61.9	17.0	19.3	—	.7	1.1	1130
	As purchased,	22.5	47.9	13.1	15.0	—	.5	1.0	880
Side,	Edible portion,	—	53.6	15.5	28.9	—	.6	1.4	1510
	As purchased,	19.3	43.3	12.4	23.3	—	.5	1.2	1215
Pork.									
Loin,	Edible portion,	—	51.1	16.4	30.4	—	.7	1.4	1590
	As purchased,	16.3	42.8	13.7	25.4	—	.5	1.3	1325
Ham, smoked,	Edible portion,	—	40.7	15.2	37.9	—	3.5	2.7	1885
	As purchased,	14.4	34.9	13.0	32.4	—	3.0	2.3	1605
Salt, fat,		—	7.9	2.0	83.6	—	2.9	3.6	3565
Bacon,	Edible portion,	—	17.8	9.6	66.0	—	3.3	3.3	2960
	As purchased,	8.1	16.4	8.7	60.6	—	3.1	3.1	2715

TABLE 61.—*(Concluded.)*

Food Materials.		Refuse.	Edible Portion. Water.	Nutrients. Digestible. Protein.	Digestible. Fat.	Digestible. Carbo-hydrates.	Digestible. Mineral Matters.	Undigestible.	Fuel Value of Digestible Nutrients.
Poultry.		%	%	%	%	%	%	%	Cal.
Chicken,	Edible portion,	—	64.5	18.8	14.8	—	.8	1.1	975
	As purchased,	26.6	47.2	13.7	11.2	—	.5	.8	730
Eggs,	Edible portion,	—	73.0	14.7	10.7	—	.8	.8	730
	As purchased,	11.2	64.8	13.0	9.5	—	.7	.8	645
Fish.									
Bluefish,	Edible portion,	—	78.5	18.6	1.2	—	1.0	.7	400
	As purchased,	48.6	40.3	9.6	.6	—	.5	.4	200
Codfish,	Edible portion,	—	82.6	15.5	.4	—	.9	.6	305
	As purchased,	29.9	58.5	10.4	.2	—	.6	.4	200
Cod, salt,	Edible portion,	—	53.6	21.0	.4	—	18.5	6.5	410
	As purchased,	24.9	40.3	15.7	.4	—	13.8	4.9	310
Salmon, canned,		—	64.1	20.4	11.3	1.0	1.8	1.4	875
Oysters, solids,		—	88.3	5.9	1.3	3.3	.8	.4	230
Butter,		—	—	—	80.0	—	—	2.4	3375
Milk, whole,		—	87.0	3.2	3.9	5.0	.5	.4	320
Milk, skim,		—	90.5	3.3	.3	5.1	.5	.3	170
Cheese,		—	34.3	25.6	32.5	2.3	2.9	2.4	1890
VEGETABLE FOOD.									
Buckwheat flour,		—	14.2	4.9	.9	76.6	.6	2.8	1555
Corn meal,		—	12.4	7.9	2.2	73.4	.8	3.3	1600
Oatmeal,		—	7.2	14.1	6.5	65.6	1.6	5.0	1755
Rye meal,		—	12.9	5.8	.8	77.1	.5	2.9	1575
Wheat flour,		—	12.0	9.7	1.0	73.6	.3	3.4	1590
Wheat bread,		—	35.3	8.0	1.1	51.9	.8	2.9	1160
Rye bread,		—	33.5	8.4	.5	53.4	1.1	3.1	1170
Crackers, milk,		—	6.1	8.9	11.3	67.7	1.4	4.6	1900
Sugar, granulated,		—	—	—	—	98.0	—	2.0	1825
Beans, dry,		—	13.1	17.9	1.6	56.1	2.7	8.6	1440
Beets,	Edible portion,	—	87.5	1.2	.1	9.3	.8	1.1	200
	As purchased,	20.0	70.0	1.0	.1	7.4	.7	.8	160
Cabbage,	Edible portion,	—	90.9	1.5	.3	5.4	.9	1.0	140
	As purchased,	15.0	77.3	1.3	.3	4.6	.8	.7	120
Onions,	Edible portion,	—	87.1	1.4	.4	9.7	.5	.9	225
	As purchased,	10.0	78.4	1.2	.4	8.7	.4	.9	200
Potatoes,	Edible portion,	—	78.0	1.8	.1	17.9	.7	1.5	370
	As purchased,	15.0	66.3	1.5	.1	15.2	.5	1.4	315
Sweet potatoes,	Edible portion,	—	69.0	1.4	.6	26.0	.8	2.2	530
	As purchased,	15.0	58.7	1.2	.5	22.1	.7	1.8	455
Apples,	Edible portion,	—	83.5	.3	.5	14.4	.3	1.0	295
	As purchased,	25.0	62.6	.2	.4	10.8	.2	.8	220
Bananas,	Edible portion,	—	75.2	1.0	.6	20.9	.7	1.6	430
	As purchased,	40.0	45.1	.6	.4	12.5	.5	.9	260
Strawberries,	Edible portion,	—	90.4	.8	.6	6.9	.5	.8	170
	As purchased,	10.0	81.4	.7	.5	6.3	.4	.7	150

FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The field experiments conducted by the Station during the year 1896 have been carried out mainly on the Station land at Storrs. They have been almost wholly a continuation of experiments which were designed to run through a period of years, and of which accounts have been given in previous reports. The field work has been in four lines:—

1. Special nitrogen experiments on corn, legumes, and grasses; for the purpose of studying the effect of different quantities of nitrogen on the yield and composition of the crop.

2. A rotation soil test on the Station land for the purpose of studying the deficiencies of the soil and the needs of different crops for the different fertilizer ingredients.

3. Experiments on the improvement of light "plain land" soils by green manuring with legumes. These experiments will have to be continued at least another year before results of material value can be obtained.

4. The growing of different kinds of forage crops for use in soiling experiments with milch cows, and for digestion experiments with sheep. The main value of these experiments is in a study of the digestibility of soiling crops in different stages of growth. (See account of digestion experiments with sheep, beyond.)

SPECIAL NITROGEN EXPERIMENTS.

In the fall of 1894 the plots on the field at the Station that had been used for several years for special nitrogen experiments on grasses, were subdivided into a number of smaller plots of one-fiftieth of an acre each, and experiments were planned for the purpose of comparing the effects of fertilizers on the yield and composition of two varieties of corn, and several varieties of legumes. Each of the smaller plots was to have the same treatment as regards kinds and proportions of

fertilizers as the larger plots had received in the earlier experiments on grass. The plan of the experiment included a series of ten plots, two to be without fertilizers, and eight to have a fixed quantity, in each case, of "mixed minerals"—dissolved bone-black and muriate of potash. Of the eight fertilized plots, two were to have no nitrogen and six were to receive different kinds and amounts of nitrogen. On three of these last the nitrogen was applied in the form of nitrate of soda, supplying nitrogen at the rate of 25, 50 and 75 pounds per acre respectively, and the other three were supplied with sulphate of ammonia furnishing nitrogen at the same rates of 25, 50 and 75 pounds per acre.

Owing to the smallness of the plots it cannot be expected that the experiments will prove as valuable as regards the effect of fertilizers on yields as might be obtained on larger plots. It was thought, however, that the most important part of the experiment would be the effects of fertilizers on the composition of the plants, and that the results would be nearly as valuable from smaller plots as from larger, and a greater number of crops could thus be experimented upon.

EXPERIMENTS ON CORN.

This experiment was undertaken for the purpose of studying the effect of nitrogenous fertilizers on the yield and composition of two varieties of corn which differed quite widely in composition at the start; these two varieties to be grown for a period of years, with the same kinds and amounts of fertilizers. The seed was to be saved from the crop of each plot each year and planted again on the same plot the following year. This is the second year of the experiment. One variety of corn—the white flint—was chosen because it contained relatively large quantities of protein (13.0 per cent.) in the dry matter, while the other variety—a yellow flint—had been grown upon poor soil for many years, and contained relatively small quantities of protein (11.2 per cent.) in the dry matter. The two varieties were grown at opposite ends of the original large plots and were about 300 feet apart. The first season (1895) the seed of the two kinds mixed slightly, but care was taken to select the distinct kinds for seed in 1896. In that year the two kinds were planted about a week apart, and thus mixing was prevented.

The white flint corn was planted May 30, in check rows three feet apart each way, and the yellow flint was planted six days later. The fertilizer was applied to both series of plots broadcast on the 9th of June.

The growth on the plots without fertilizer was small. The plants were spindling, and of a pale color throughout the season. The mixed mineral plots (6*a* and 6*b*) made nearly as heavy a growth of stalks as some of the plots receiving nitrogen, but the plants were pale colored throughout the season, and did not develop as heavy a growth of ears. The yields on the nitrogen plots were in most cases much smaller where only 25 pounds of nitrogen per acre were used than where larger amounts were added. The increased yields, however, where larger quantities of nitrogen were used did not seem to correspond to the increase in nitrogen. For example, the crop obtained where 50 pounds of nitrogen was used, was in most cases nearly or quite equal to that obtained where 75 pounds were added.

TABLE 62.

SPECIAL NITROGEN EXPERIMENT ON YELLOW FLINT CORN.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

Plot No.	Fertilizers.	Weight of Fertilizers.	Cost of Fertilizers.	Yield per Plot. (1-50 Acre.) Corn (ears).	Yield per Plot. (1-50 Acre.) Stover.	Percentage of Shelled Corn.	Yield per Acre of Shelled Corn. (11 % Water.)		Stover per Acre. (25 % Water.)	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	%	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - - -	—	—	56	63	74.1	1671	29.8	2365	—
7	Mix'd Minerals, as No. 6*a*, Nit. of Soda (25 lbs. N.),	480 160	12.00	109	103	72.1	3114	55.6	3962	26.9
8	Mix'd Minerals, as No. 6*a*, Nit. of Soda (50 lbs. N.),	480 320	15.96	133	111	74.2	3933	70.2	3966	41.5
9	Mix'd Minerals, as No. 6*a*, Nit. of Soda (75 lbs. N.),	480 480	19.92	139	96	72.5	4066	72.6	3827	43.9
6*a*	Dis. Bone-black, } Mxd Mur. of Potash, } Min.	320 160	8.00	69	76	74.6	2113	37.7	2847	9.0
10	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	12.44	125	124	75.6	3973	70.9	4762	42.2
11	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	16.88	131	134	72.6	3793	67.7	4136	39.0
12	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	21.32	140	116	73.9	4500	80.3	3959	52.6
00	Nothing, - - -	—	—	53	66	70.6	1538	27.5	2367	—
6*b*	Mix'd Minerals, as No. 6*a*,	480	8.00	94	93	70.4	2724	48.6	3497	20.9

TABLE 63.

SPECIAL NITROGEN EXPERIMENT ON WHITE FLINT CORN.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

Plot No.	Fertilizers.	Weight of Fertilizers.	Cost of Fertilizers.	Yield per Plot. (1-50 Acre.) Corn (ears).	Yield per Plot. (1-50 Acre.) Stover.	Percentage of Shelled Corn.	Yield per Acre of Shelled Corn. (11 % Water.)		Stover per Acre. (25 % Water.)	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	%	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - - - -	—	—	57	28	79.4	2137	32.8	1559	—
7	Mix'd Minerals, as No. 6*a*, Nit. of Soda (25 lbs. N.),	480 160	12.00	93	66	80.1	3318	59.3	3414	30.2
8	Mix'd Minerals, as No. 6*a*, Nit. of Soda (50 lbs. N.),	480 320	15.96	111	62	79.8	3932	70.2	3079	41.1
9	Mix'd Minerals, as No. 6*a*, Nit. of Soda (75 lbs. N.),	480 480	19.92	114	68	75.9	3829	68.4	3511	39.3
6*a*	Dis. Bone-black, Mur. of Potash, } Mxd Min.	320 160	8.00	75	54	80.4	2867	51.2	2776	22.1
10	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	12.44	78	70	78.2	2676	47.8	3296	18.7
11	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	16.88	109	64	79.8	3858	68.8	2925	39.7
12	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	21.32	118	78	78.5	4063	72.5	3605	43.4
00	Nothing, - - - -	—	—	43	25	78.0	1415	25.3	1378	—
6*b*	Mix'd Minerals, as No. 6*a*,	480	8.00	86	59	80.4	3012	53.8	2946	24.7

INFLUENCE OF NITROGEN ON THE PERCENTAGE OF PROTEIN.

The tables which follow give the percentages and yields of dry matter and the percentages and yields of protein per acre for the two varieties of corn. From these tables it will be seen that the crop on the "nothing" plots (those which had no fertilizer) often gave a higher percentage of protein than was obtained on many of the fertilized plots. Earlier work done by this Station shows that "poor" or immature corn generally has a higher percentage of protein than fully matured corn. This is believed to be due to the fact that in the immature condition of plants and seeds the percentage of nitrogen is naturally greater, while as the plants or seeds advance toward maturity the proportion of carbohydrates (starch, etc.,) is increased, and the proportion of protein is thus relatively lessened. In the case of the nothing plots the growth ceases before the corn reaches maturity. For

this reason it is much fairer in judging of the effects of nitrogen to compare the composition of the crop on the mineral plots (6*a* and 6*b*) with that on plots having nitrogen in addition to the mineral fertilizers. Thus, if we compare plots 7, 8, and 9 with 6*a* or 6*b*, we find that the percentages of protein* in both corn and stover are higher where nitrogen was used, and that the percentage of protein gradually increases with the quantity of nitrogen used. This is likewise true, with one exception, plot 11, in the corresponding plots 10, 11 and 12. This tends to show that the benefits obtained from the use of nitrogenous fertilizers on corn are two-fold. Up to a certain limit they tend to increase the yield of crop, and likewise increase the proportion of protein, and hence the feeding value of the crop.

Table 64.

SPECIAL NITROGEN EXPERIMENT ON CORN.

Percentages and pounds per acre of dry matter and of protein.

Plot No.	Fertilizers. (*North Plots.*)	Weight of Fertilizers.	Yellow Flint Corn. Grain.				Yellow Flint Corn. Stover.			
			Dry Matter.		Protein.*		Dry Matter.		Protein.	
		Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.
0	Nothing, - - - -	—	71.6	1486	9.90	147	56.3	1774	7.75	137
7	Mix'd Minerals, as No. 6*a*, Nit. of Soda (25 lbs. N.),	480 160	70.5	2769	9.34	259	57.7	2972	5.28	157
8	Mix'd Minerals, as No. 6*a*, Nit. of Soda (50 lbs. N.),	480 320	70.9	3496	10.76	376	53.6	2975	6.91	206
9	Mix'd Minerals, as No. 6*a*, Nit. of Soda (75 lbs. N.),	480 480	71.7	3615	11.68	422	59.8	2870	7.04	202
6*a*	Dis. Bone-black, } Mxd Mur. of Potash, } Min.	320 160	73.0	1879	9.31	175	56.2	2135	5.37	115
10	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	74.7	3532	10.20	360	57.6	3572	5.45	195
11	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	70.9	3372	9.87	333	46.3	3102	6.25	194
12	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	77.3	4000	11.13	445	51.2	2964	8.54	253
00	Nothing, - - - -	—	73.1	1367	10.22	140	53.9	1775	6.70	119
6*b*	Mix'd Minerals, as No. 6*a*,	480	73.2	2422	9.38	227	56.4	2623	5.07	133

* The protein is estimated by multiplying the nitrogen by 6.25. The percentages of protein are those of the dry matter.

TABLE 65.

SPECIAL NITROGEN EXPERIMENT ON CORN.

Percentages and pounds per acre of dry matter and of protein.

Plot No.	FERTILIZERS. (*South Plots.*)	Weight of Fertilizers.	White Flint Corn. Grain. Dry Matter.		Protein. N. × 6.25.		White Flint Corn. Stover. Dry Matter.		Protein. N. × 6.25.	
		Lbs.	%	Lbs.	%*	Lbs.	%	Lbs.	%	Lbs.
0	Nothing, - - -	—	83.9	1899	11.14	212	83.5	1169	7.33	86
7	Mix'd Minerals, as No. 6*a*, Nit. of Soda (25 lbs. N.),	480 160	79.2	2950	10.17	300	77.6	2560	4.89	125
8	Mix'd Minerals, as No. 6*a*, Nit. of Soda (50 lbs. N.),	480 320	78.9	3495	11.40	398	74.5	2309	5.97	138
9	Mix'd Minerals, as No. 6*a*, Nit. of Soda (75 lbs. N.),	480 480	78.7	3404	12.46	424	77.4	2633	8.30	219
6*a*	Dis. Bone-black, } Mxd Mur. of Potash, } Min.	320 160	84.5	2548	9.58	244	77.1	2082	4.77	99
10	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	78.0	2378	10.91	259	70.6	2472	4.70	116
11	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	78.8	3429	10.96	376	68.5	2194	5.81	127
12	Mix'd Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	78.0	3611	12.04	435	69.3	2704	6.99	189
00	Nothing, - - -	—	75.0	1258	11.21	141	82.6	1034	6.37	66
6*b*	Mix'd Minerals, as No. 6*a*,	480	77.5	2678	9.82	263	74.9	2210	4.52	100

* Percentages of protein in dry matter.

EXPERIMENTS ON COW PEAS.

On two series of plots of one-fiftieth of an acre each, similar to those on which the corn was grown, cow peas were planted. The results obtained on the two sets of plots were added together and are reported as one experiment. The kinds and amounts of fertilizers per plot were exactly the same as on the corn plots. The seed was planted in drills, June 5th, at the rate of about one bushel per acre. In this experiment it is impossible to use the seed of the crop of the year before, as the cow peas do not mature seed in this climate. The seed has been obtained each year from Tennessee. It will be noticed from the table which follows that there was a large increase in yield on the mixed mineral plots (6*a* and 6*b*) over that obtained on the nothing plots, and that in the case of the nitrate of soda plots, 7, 8 and 9, there was quite an increase over that obtained from mineral fertilizers alone. The increase derived from the use of nitrogen was not very marked, however, as it will be

seen that the largest yield, 10.4 tons per acre, was obtained where only 25 pounds of nitrogen were added. Both in 1895 and 1896 the larger quantities of sulphate of ammonia seemed to depress the yields. The hypothesis has been suggested that the repeated use of sulphate of ammonia through quite a period of years may have induced an acid condition of the soil. This might be unfavorable to the growth and development of bacteria and to the formation of tubercles. It has been noticed that the proportion of tubercles on the roots of the plants on these plots was much less than on corresponding plots where nitrate of soda was employed. As to the correctness of the hypothesis and the advantage of using slaked lime to correct the acidity, we have no experimental data to warrant any conclusions.

TABLE 66.

SPECIAL NITROGEN EXPERIMENT ON COW PEA FODDER.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

Plot No.	FERTILIZERS.	Weight of Fertilizers.	Cost of Fertilizers.	COW PEA FODDER. Yield per Plot. (1-25 Acre.)	Yield per Acre. (80 % Water.)		Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	Tons.	Lbs.
0	Nothing, - - - - -	—	—	450	10295	5.1	—
7	Mixed Minerals, as No. 6*a*, - Nitrate of Soda (25 lbs. N.), -	480 160	12.00	938	20750	10.4	10198
8	Mixed Minerals, as No. 6*a*, - Nitrate of Soda (50 lbs. N.), -	480 320	15.96	925	19770	9.9	9217
9	Mixed Minerals, as No. 6*a*, - Nitrate of Soda (75 lbs. N.), -	480 480	19.92	985	20440	10.2	9761
6*a*	Dis. Bone-black, } Mixed Mur. of Potash, } Minerals,	320 160	8.00	923	17420	8.7	6856
10	Mixed Minerals, as No. 6*a*, - Sulph. of Am. (25 lbs. N.), -	480 120	12.44	866	17860	8.9	8064
11	Mixed Minerals, as No. 6*a*, - Sulph. of Am. (50 lbs. N.), -	480 240	16.88	826	17760	8.9	4623
12	Mixed Minerals, as No. 6*a*, - Sulph. of Am. (75 lbs. N.), -	480 360	21.32	818	15030	7.5	6420
00	Nothing, - - - - -	—	—	414	10815	5.4	—
6*b*	Mixed Minerals, as No. 6*a*, -	480	8.00	828	17655	8.8	7104

TABLE 67.

SPECIAL NITROGEN EXPERIMENT ON COW PEAS.

Percentages and pounds per acre of dry matter and of protein.

Plot No.	Fertilizers.	Wt. of Fertilizer.	Dry Matter.		Protein. N.×6.25.	
		Lbs.	%	Lbs.	% *	Lbs.
0	Nothing,	—	18.3	2059	16.8	346
7	Mixed Minerals, as No. 6*a*, / Nitrate of Soda (25 lbs. N.),	480 / 160	17.7	4150	16.8	697
8	Mixed Minerals, as No. 6*a*, / Nitrate of Soda (50 lbs. N.),	480 / 320	17.1	3954	18.9	747
9	Mixed Minerals, as No. 6*a*, / Nitrate of Soda (75 lbs. N.),	480 / 480	16.6	4088	19.5	797
6*a*	Dissolved Bone-black, / Muriate of Potash, } Mixed Minerals,	320 / 160	15.1	3488	19.7	687
10	Mixed Minerals, as No. 6*a*, / Sulphate of Ammonia (25 lbs. N.),	480 / 120	16.5	3572	19.0	679
11	Mixed Minerals, as No. 6*a*, / Sulphate of Ammonia (50 lbs. N.),	480 / 240	17.2	3552	16.6	590
12	Mixed Minerals, as No. 6*a*, / Sulphate of Ammonia (75 lbs. N.),	480 / 360	14.7	3006	21.4	643
00	Nothing,	—	20.9	2163	20.0	433
6*b*	Mixed Minerals, as No. 6*a*,	480	17.4	3531	18.2	643

* Percentages of protein in dry matter.

YIELDS OF PROTEIN PER ACRE.

It is of interest to note the percentages and total yields of protein per acre in the cow peas as compared with the corn where the same kinds and amounts of fertilizers were used. In the case of the cow peas there seems to be very little relationship between the percentages of protein in the crop and the quantity of nitrogen used in the fertilizer. The average yield of protein on the plots having only mineral fertilizers was 19 per cent., while the average yield on the three plots having nitrate of soda was 18.4 per cent., and on the three plots having sulphate of ammonia, 19 per cent. The yields of dry matter per acre were not much more than half as much from the cow peas as was obtained from the corn and stover on similar plots, yet the total yield of protein per acre was greater in all cases with the cow peas than on the corresponding plots with corn.

This emphasizes the high feeding value of the cow peas. This crop has been used for several years on the College farm,

both for feeding green and for mixing with corn for producing a mixed silage with a higher percentage of protein than would be obtained from corn silage alone.

SOIL TEST EXPERIMENT BY THE STATION.

This experiment is the seventh in a series planned as a rotation soil test experiment, the same kinds of fertilizers being used on the same plots year after year. Beginning with 1890, the crops grown on this field have been corn, potatoes, oats, cow peas, corn, potatoes, and oats.

ARRANGEMENT OF PLOTS IN STATION EXPERIMENT.

UNMANURED STRIPS SEPARATE THE PLOTS.

EAST.

NORTH.

Plot o.	Plot Y.
Plot A.	Plot X.
Plot B.	Plot ooo.
Plot C.	Plot G.
Plot oo.	Plot F.
Plot D.	Plot E.
Plot E.	Plot D.
Plot F.	Plot oo.
Plot G.	Plot C.
Plot ooo.	Plot B.
Plot X.	Plot A.
Plot Y.	Plot o.

SOUTH.

WEST.

The field slopes gently to the south, but not enough to cause serious washing. The soil is a heavy loam, and the subsoil is a yellow, clay loam. In 1889 it was noticed that the soil seemed to be poorer toward the west side of the field. For this reason the field was laid out into two half-acre experiments, the order of the plots on the two being reversed, as per diagram.

The yields of the duplicate plots in each case are added in estimating the yield per acre. This helps to eliminate the errors due to irregularities of soil. Beside the regular soil test, two other plots were added—one (X) with a medium

amount (10,000 pounds per acre) of manure, and in addition dissolved bone-black at the rate of 160 pounds per acre; the other (Y) with a larger quantity (16,000 pounds) of stable manure, but without bone-black.

The field was seeded to oats on the 29th of April, at the rate of two and one-third bushels per acre. The paths between the plots were seeded in the same manner as the plots. The fertilizer was applied to the plots at the rates shown in the following table, on the 30th. This is the seventh crop grown on this field since the experiment was begun, the kinds and amounts of fertilizers being the same each year. Quite a marked difference in the growth on the different plots could be observed throughout the season. On July 7th, plots having phosphoric acid applied in the fertilizer showed an increase in growth over other plots. Plots without nitrogen were pale colored, although the growth was nearly as large as on the plots with nitrogen. From the table which follows it will be seen that where only one ingredient of plant food was used (plots A, B, and C,) the nitrogen had the greatest influence on the yield, while on plots where two ingredients were combined (D, E, and F,) nitrogen and phosphoric acid (plot D) gave the best results. Plot G, with all three of the fertilizing ingredients, gave very little increase over D, to which no potash was applied. This tends to show that on the soil experimented upon potash did not prove of much value for the oat crop, while nitrogen and phosphoric acid increased the yields to a marked extent. In this respect the experiment agrees with the oat experiment of four years ago (1892) on the same plots. Experiments conducted on this field with potatoes show that potash and nitrogen had a very marked influence on the yield, while phosphoric acid gave comparatively little increase. This seems to indicate that the special needs of different crops, as well as the deficiencies of the soil, must be taken into consideration before fertilizers can be used with the best results. It will be of interest to compare the yields obtained with different crops during the past seven years, as shown in the table below the one giving the yields of oats for 1896.

TABLE 68.

SOIL TEST WITH FERTILIZERS ON OATS.

BY THE STATION, STORRS.

Plot No.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per Plot. (1-12 Acre.) Oats.	Straw.	Yield per Acre. Oats.*	Straw.	Gain over Nothing Plots.	Wgt. per Bushel.
		Lbs.	$	Lbs.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
0	Nothing, - -	—	—	79	89	29.6	1068	0.0	30.9
A	Nitrate of Soda, -	160	3.96	104	140	39.0	1680	10.6	29.3
B	Dis. Bone-black, -	320	4.40	93	116	34.9	1392	6.5	32.5
C	Muriate of Potash, -	160	3.48	74	99	27.8	1188	—.6	30.6
00	Nothing, - -	—	—	70	89	26.3	1068	0.0	29.0
D	Nitrate of Soda, - Dis. Bone-black, -	160 320	8.48	128	169	48.0	2028	19.6	33.0
E	Nitrate of Soda, - Muriate of Potash, -	160 160	7.52	110	156	41.3	1872	12.9	31.0
F	Dis. Bone-black, - Muriate of Potash, -	320 160	8.00	97	125	36.4	1500	8.0	33.6
G	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12.00	135	194	50.6	2328	22.2	34.0
000	Nothing, - -	—	—	78	92	29.3	1104	0.0	28.7
X	Stable Manure, - Dis. Bone-black, -	10000 160	18.80	130	184	48.8	2208	20.4	33.2
Y	Stable Manure, -	16000	19.20	147	195	55.1	2340	26.7	33.1

* Thirty-two pounds per bushel.

The yields obtained on this field during the past seven years are shown in the following table:

TABLE 69.

Yields on Station soil test experiment for past seven years.

Plot No.	Fertilizers.	Weight per Acre.	Corn. 1890.	Potatoes. 1891.	Oats. 1892.	Cow Peas (vines). 1893.	Corn. 1894.	Potatoes. 1895.	Oats. 1896.
		Lbs.	Bu.	Bu.	Bu.	Lbs.	Bu.	Bu.	Bu.
0	Nothing, - -	—	28.9	89	29.1	10230	33.6	55	29.6
A	Nitrate of Soda, -	160	32.4	105	36.0	10960	41.0	50	39.0
B	Dis. Bone-black, -	320	33.3	97	27.0	10710	37.6	56	34.9
C	Muriate of Potash, -	160	30.4	171	26.3	11680	40.8	88	27.8
00	Nothing, - -	—	26.7	87	24.2	9725	28.0	38	26.3
D	Nitrate of Soda, - Dis. Bone-black, -	160 320	36.1	110	37.9	12920	40.8	57	48.0
E	Nitrate of Soda, - Muriate of Potash, -	160 160	32.8	160	30.0	13335	47.6	104	41.3
F	Dis. Bone-black, - Muriate of Potash, -	320 160	34.4	214	27.8	15790	48.2	109	36.4
G	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	37.4	259	39.4	16210	58.2	129	50.6
000	Nothing, - -	—	28.5	88	22.5	12100	38.0	49	29.3
X	Stable Manure, - Dis. Bone-black, -	10000 160	44.1	210	40.9	15795	57.0	110	48.8
Y	Stable Manure, -	16000	43.6	250	41.3	15875	56.7	125	55.1

IRRIGATION IN CONNECTICUT.*

BY C. S. PHELPS.

The subject of irrigation as related to the arid regions has received special attention during the past twenty years. Millions of dollars have been expended by individuals and corporations in some half dozen of the Pacific Coast and Rocky Mountain States, in order that fruits and grains may be made to flourish on what would otherwise be barren soils, and within the past few years Congress has made liberal appropriations for investigating the best methods of agriculture by irrigation. Up to the present time, however, little has been done in the Eastern States in the use of irrigation either on farm, garden, or orchard crops. But its great value has been demonstrated in a few striking instances by some of our leading fruit growers, and these instances, together with the general interest that is being manifested in the subject, show the need of inquiry. Within the past two years there has been a lively agitation of the subject through the agricultural press of the East, and farmers and small fruit growers are beginning to appreciate the value of artificial watering, and an increasing demand seems to exist for all the information obtainable on the subject.

In the Eastern portions of this country the intensive system of agriculture is rapidly replacing the extensive. This has become necessary because of the rapidly increasing population and a corresponding increase in the value of lands. In the past fifty years the agriculture of New England has been entirely changed. A system of mixed husbandry has been largely replaced by special branches of farming. The many thriving manufacturing cities and towns that are being built up have caused a great demand for fruits and vegetables.

* The substance of this article is about to appear as part of a longer article by the author in a Bulletin of the Office of Experiment Stations of the United States Department of Agriculture.

These products have proven especially profitable where markets are near at hand. The high value per acre and the active and increasing demand for fresh fruits and vegetables, have induced many of our farmers to enter upon the production of these crops, and it is in such lines of farming as fruit growing and market gardening that irrigation has its highest value. In regions where the value of farm lands is high the farmer must obtain large crops, and those of the best quality, in order to pay taxes and obtain a fair profit on his investment, and to do this he must not only cultivate highly, but adopt every means within his power to prevent losses. Where the cost of cultivation is large the losses from drouth are felt all the more severely, as the expenses are essentially the same whether a half crop or a full crop is harvested. In the Eastern part of this country drouths are not usually of long duration, but short severe drouths are common, and they cause heavy losses to market gardeners and fruit growers. Losses of from one to two hundred dollars per acre as a result of a few weeks' drouth are not uncommon. The area devoted to strawberry culture the past season in Connecticut is estimated at not less than 500 acres. With this total acreage a loss of $100 per acre means $50,000 on a single crop, for one small State.

The experience of practical men and the experiments cited beyond indicate that an investment in an irrigation plant where market garden crops and small fruits are grown will pay exceptionally good interest. This is because of the high value per acre of such crops and the fact that in many instances the cost of getting and applying the water is small. The cost of applying water for strawberries, when an irrigation plant is once established, need not exceed $10 per acre, while the increased yields resulting from its use may often amount to $100 to $200 per acre.

IMPORTANCE OF WATER IN PLANT GROWTH.

The most important factors influencing the growth of plants are water, food, heat and light. The influence of the last three of these has been quite extensively studied, but with regard to the relation of water, one of the most important of all of these factors, but little is known. The importance of an adequate supply of water in the growth of plants is well

illustrated in greenhouse culture, where nearly all of the soil receives a thorough wetting once in two or three days. Here, also, heat and light are to a great extent under control. In field culture heat and light cannot be controlled, but food and water may. The subject of fertilizers and manures and their influence on the growth of farm crops has been carefully investigated during the past twenty-five years. Fertilizers, however, are of little use without an abundance of water to render them available for the plant. One of the most serious drawbacks in conducting field experiments with fertilizers is the fact that the water supply cannot readily be regulated. It frequently happens that in seasons of drouth the value of such field experiments is almost destroyed; or if deductions are drawn from them without regard to the moisture conditions of the particular season, such deductions are apt to be very misleading.

It is important to study all possible means for conserving the water in the soil by preventing its escape, and thus retaining it where it will be available for the plant when most needed. Much can be done to this end by the addition of humus, either in the form of stable manure, or other decaying vegetable or animal matter, or by placing some suitable mulch on the surface of the ground, or by forming a mulch from the surface layers of the soil by frequent cultivation; but with all these helps crops will at times suffer for want of the necessary water to keep up a vigorous growth, unless an artificial supply is provided.

A large proportion of the weight of most plants is water. This is familiar to all, in the fact so readily observed, that plants and fruits lose weight rapidly in drying. In every 100 pounds of freshly cut grass there are from seventy to eighty pounds of water; while clovers frequently contain over eighty per cent. Nearly all of our common fruits, such as strawberries, raspberries, pears, and peaches, contain from eighty to ninety-two per cent. of water. The importance of this to the farmer is seen in the fact that when he sells such crops off the farm he is mainly disposing of water and a small amount of mineral salts.

The water held in the substance of the plant, however, represents only a small part of that needed in its growth; a large amount is transpired through the foliage during the period of the plant's development.

It has been estimated that a crop of hay at two tons per acre, or about six and one-half tons of fresh grass, will evaporate during its season of growth about 525 tons of water; that an average crop of wheat, of 720 pounds of grain and 1500 pounds of straw to the acre, will evaporate about 260 tons of water, or, in other words, according to these estimates, every ton of green grass evaporates through its foliage during the period of growth about eighty-one tons of water, and in drying, this ton of grass loses about two-thirds of its weight, so that one-third of a ton of hay (667 pounds), utilizes in its growth about eighty-one tons of water. An inch of rainfall is equal to 113 tons of water per acre. The above figures indicate that the water evaporated by the hay crop would equal about four and six-tenths inches of water and the wheat crop two and three-tenths inches. These figures, of course, only represent averages. In very moist times evaporation would be checked and in dry times it would be increased. In other words, at the times when the plant uses water most rapidly there is the least available amount from the rainfall.

The importance of water in the growth of crops may again be illustrated in a remarkable way by the experiments in water culture which have been carried on for many years, especially in the German Experiment Stations. In these experiments plants are grown, not in soil at all, but with their roots immersed in water. The seeds are allowed to sprout in some convenient medium, as sand or moist cotton, or in an apparatus devised for the purpose. When the roots are started the plantlets are suspended at the tops of jars so that the roots dip into water with which the jars are nearly filled. The water in the jars holds in solution the materials which the plantlets ordinarily obtain from the soil. The roots find this material in the water, use it, and the plants grow. Solutions containing all the essential soil ingredients of plant food are called normal solutions. In these plants are raised as large and healthy and in every way as perfect as those grown in even the richest soil.

The same principle as that illustrated in water culture is involved in all growth of plants by irrigation. In the irrigated regions of Lombardy, in Italy, eight or nine or more crops of grass are frequently cut in a single season. On the same land

and with the same manuring, but without the irrigation, only ordinary crops could be obtained.

A large and variable quantity of water is evaporated directly from the soil. The amount of this depends upon several conditions, the chief of which are the state of the weather, the kind of crop on the soil, the amount of cultivation, and whether or not the soil is mulched. In times when rainfall is insufficient for the best growth of crops the atmospheric conditions are usually such as to favor the evaporation of moisture from the soil. The amount of evaporation that takes place depends upon the amount of wind that may be blowing over the soil, and the degree of saturation of the air. Meteorologic data showing the relative humidity of the air frequently indicate that on hot, dry days the air contains as low as from twenty to fifty per cent. of its water-holding capacity. Under such conditions, especially in connection with winds, the moisture evaporates from the soil very rapidly. The shade afforded by crops like grass and small grains tends to lessen the amount of evaporation from the soil, while crops which do not shade the ground as much furnish conditions more favorable for the escape of moisture. It is a well-known fact that mulch in the form of coarse hay, straw, etc., tends to prevent the escape of moisture. This, together with the cleaner fruit that results, is one of the reasons for using such materials on strawberry fields. Frequent stirring of the surface soil by cultivation has much the same effect in preventing the escape of moisture as the direct use of mulch. In the experiments by the writer, on the evaporation of moisture from heavy loam and light loam soils, the soils in a part of each series were frequently stirred at the surface, while the others were not stirred. The average loss of moisture from the soil not stirred was equal to one and one-third inches, while the average loss from the stirred soil was three-quarters of an inch. This means that not far from twice as much water was evaporated from the soil left in a naturally compact condition over that lost where the surface was mulched by frequent stirring.

It is frequently the case that plants require a very large amount of water during a short period of time at certain seasons of the year. This is especially true when they are developing fruit. An abundant supply of water just before

and at the ripening season of strawberries usually means a good crop, while a ten days' drouth at this time will often reduce the crop one-third to one-half below a normal yield. Nearly every farmer knows that plenty of rainfall when potatoes are "setting" is favorable to a large crop, while drouth at this time is almost sure to seriously diminish the yield. Short periods of drouth will often so check plant growth that even if these periods be followed by copious rainfalls the crop does not fully recover itself. This is especially true with grass. A short hay crop is almost certain to result if the rainfall is small during the month of May.

NEED OF IRRIGATION IN CONNECTICUT.

The majority of people fail to realize that irrigation has any place in New England agriculture. It is generally thought that our annual rainfall is sufficient to meet the needs of most, if not all, of our farm crops, and that any considerable expenditure of money for irrigation would not repay the expense, unless in very exceptional cases. The rainfall, however, is very unevenly distributed throughout the year. Short, severe drouths are a characteristic of this climate. A high temperature, accompanied by drying winds, will, in a week's time, frequently cause our crops to wilt, and in less than two weeks the crop prospects may be nearly ruined as a result of the absence of the water needed to keep up a vigorous growth.

A rainfall of three inches per month, if fairly well distributed throughout the month, will probably produce an average growth of most farm crops. With less than this amount of rainfall many crops fail to make a normal development. During the past eight years the Storrs Experiment Station has made observations on rainfall during the growing season in about a dozen different places in the State, and from these and others made for the New England Meteorological Society are taken the following figures for the rainfall for the three summer months. From this table it will be seen that the rainfall has been below three inches for June, seven years out of eight; for July, three years; and for August, one year.

TABLE 70.

Rainfall in Connecticut during the summer months, 1888–95.

YEAR.	June.	July.	August.	Number of Stations.
	Inches.	Inches.	Inches.	
1888, - - - - - - -	1.69	2.05	5.30	18
1889, - - - - - - -	3.83	11.35	3.92	20
1890, - - - - - - -	2.96	4.29	4.29	17
1891, - - - - - - -	2.47	4.24	3.81	20
1892, - - - - - - -	2.65	3.80	4.35	26
1893, - - - - - - -	2.65	2.12	4.69	22
1894, - - - - - - -	.75	1.55	1.81	23
1895, - - - - - - -	2.74	4.36	4.54	21
Average, - - - - - -	**2.47**	**4.22**	**4.09**	—

The rainfall for the growing season (May to September), were it evenly distributed through the different months, would usually prove sufficient for the needs of most crops, but from the above table it will be seen that the rainfall for different months is very irregular. While the water which accumulates in the soil during the portions of the year when crops are not growing may be of some benefit to crops, yet a large part of the water used, especially where the ground water is quite a distance below the surface, must come from the rain that falls while the crops are growing. A remarkable instance of the excess of rainfall which often occurs when crops need the water least, and a deficiency during those months when crops use water most largely, is shown in the rainfall data at Storrs, Conn., for the year 1895. The five summer months, from May 1st to September 30th, showed a total rainfall of 14.5 inches, while the two succeeding months, October and November, gave a rainfall of 13.7 inches.

There are very few seasons during some part of which a drouth of more or less severity does not occur. With crops like strawberries, raspberries, early potatoes, and onions, a lack of rain for two or three weeks may lessen the crop by one-half or more. A striking illustration of the injury caused by short drouths was seen in the season of 1895, on one of the farms in this State where irrigation was being put into operation for the first time. A field of strawberries that had been set out in the spring of 1894 was on too high ground to be reached by water conducted from the storage pond. A field of the same size on another part of the farm was sprinkled from pipes

laid on the surface. The irrigated field, with only three applications of water, gave a yield two and two-thirds times greater than that obtained where no water was applied.

A strong argument in favor of irrigation in Connecticut is found in the high value per acre of many farm and garden crops. The following table shows the range of value per acre for some small fruits and market-garden crops as given by practical farmers, when these crops have not been irrigated:

Strawberries,	-	$200 to $450	Celery,	- -	$200 to $300
Raspberries,	-	200 to 400	Onions,	- -	150 to 300
Asparagus, -	-	100 to 200	Muskmelons,	-	300
Cauliflower,	-	200 to 400			

It will readily be seen that a loss of one-half on some of these crops, when five or six acres are grown, would cover quite an outlay for water. The two men in Connecticut who have made the most extensive use of irrigation both state that the cost of the irrigation plant was returned the first season by the increased crops obtained where water was applied.

With crops like strawberries and raspberries the benefits derived from irrigation represent only a few weeks' labor and a small expenditure of money. So great is the gain derived from having an abundance of water for these crops at the right time that good profits have been obtained by the use of a road engine and force pump. In many places this form of power could be hired for a few days and large profits obtained from its use.

Before farming products were shipped by rail long distances the prices obtained for the crop in any locality depended largely upon the supply in that immediate vicinity. If the season was not a favorable one for any particular crop, and the yields were light, the increased prices obtained often counterbalanced the deficiency in the yield, so that the weather conditions did not so largely regulate the profits. To-day, however, if there is a shortage in any crop in one locality, the market, except in the case of perishable products, may be stocked from long distances away where the weather conditions were perhaps favorable for large yields. The profits obtained by local growers are thus largely dependent upon the seasons, and it frequently happens that the season of poor crops resulting from lack of rainfall nearly or quite uses up the profits of favorable seasons.

METHODS OF IRRIGATION IN USE IN CONNECTICUT.

The sources of water for irrigating purposes in Connecticut are mainly from small natural streams, from ponds, and from springs. No instances are known of the use of water from wells for irrigating purposes in this State. The water is usually stored either in open ponds or in large tanks. When the source is high enough the water is conducted on to the fields through open ditches or pipes, and this is, of course, the cheapest and simplest method. There are, however, many instances in Connecticut where the water can only be made available by some form of power, as it is below the fields upon which it is wanted. There are two farms in this State where powerful rams have been very successfully used; in such cases the water is generally conducted through, and distributed upon, the fields by means of pipes. Where a ram or other pumping appliance is used it is necessary, in order to reduce the expense, to economize on the use of water and to prevent losses by evaporation. For these reasons it has been found more economical to apply the water from pipes distributed over the fields, the water being sometimes allowed to flow between the rows from pipes laid along one end of the field. In other cases it is applied by spraying. Where the water is conducted to the field in ditches, as is successfully done in several instances in this State, it is distributed over the surface by means of small trenches.

RAMS.

Rams are one of the most economical sources of power for raising water. With the ram the pressure caused by a slight fall of the water from a canal or pond compresses the air in a heavy iron cylinder and this air pressure lifts the water. The amount of work a ram will do depends mainly upon the pressure of water. Considerable water must be available, as only a small portion of the total amount that passes into the ram can be pumped. The ram used on the farm of Mr. J. C. Eddy, of Simsbury, is one of as great capacity as any we have found; in fact this particular form is just being developed, none having as yet been put upon the market. It is run by a 6-inch drive pipe, the water having a fall of seven feet from the canal to the plunger. It lifts the water to a height of seventy feet

through a 2½-inch pipe, a distance of eighty rods, giving a flow into the storage pond of about ten gallons per minute. The only ram of similar capacity of which we have learned is manufactured by the Rife Co., of Roanoke, Va. The ram used by Mr. E. C. Warner, of North Haven, is a No. 10 Douglas Ram, manufactured at Middletown, Conn. This is run by a 6-inch drivepipe, the water falling seven feet to the plunger. It throws water into two large tanks at a height of sixty feet—600 feet distant—at the rate of five to six gallons per minute.

WINDMILLS.

Where only a comparatively small quantity of water is wanted, enough for a few acres at different times during the season, a windmill is perhaps the cheapest source of power, and will prove quite effectual. The storage can best be arranged for in a deep tank or cistern where the evaporation can be controlled by covering. The water can be distributed through pipes and applied by sprinkling, if the fall from the place of storage to the fields is enough to give good pressure.

FLOWAGE SYSTEM.

New England furnishes many conditions favorable for this system of irrigation. Among these may be mentioned the unevenness of the surface, the many small streams with considerable fall giving plenty of available water, and the fact that the terrace and alluvial soil formations of our river valleys are greatly benefited by irrigation. These alluvial and terrace formations are generally light soils with porous subsoils which suffer readily from drouth. Where this plan of irrigating is used in Connecticut the outlay is comparatively slight.

The expense for damming a small stream and thus getting a large storage pond is very light, and there are many places where the fall is favorable for conveying the water. Open ditches are used for conducting the water to the fields, and if the slope of the land to be irrigated is slight the water can be entirely distributed by small trenches. Some times streams that would be nearly or entirely dry late in the summer will furnish an abundance of water for such crops as strawberries and raspberries, grass and early potatoes, which require irrigating, if at all, before midsummer. In many cases the water

might also be utilized for furnishing power for cutting feed and sawing wood, and a conveniently located pond for getting ice in winter for the dairy and household, is a need felt by nearly all farmers.

IRRIGATION PLANTS IN USE IN CONNECTICUT.

There are several irrigation plants in active operation in this State at the present time, located in the towns of Simsbury, North Haven, Meriden, Glastonbury, Hamden, Thomaston, and South Manchester. These are the only ones known to the writer that are operated upon a commercial basis.

IRRIGATION ON THE FARM OF A. J. COE, MERIDEN.

Irrigation was commenced on Mr. Coe's farm by his father about the year 1840, the water being used for the next twenty years mainly upon the grass crop, although corn, potatoes, and other crops were irrigated whenever the rainfall was deficient. In 1863 Mr. Coe began to use the water on strawberries and raspberries, and has used it every year since whenever drouths seemed to make its use necessary. In 1895 he was using it on the two crops just mentioned, and upon tomatoes, asparagus, and cabbage.

The source of the water is a small stream, that, during seasons of average rainfall, would just about flow through a 6-inch pipe without pressure. The water is stored in two large ponds. The upper one is used mainly for getting ice for very large icehouses, and to supply power for cutting feed and wood. The smaller pond, a little lower down the stream, is so located that the water can be conducted through a ditch for a distance of about forty rods and then distributed over the field in small ditches. The amount of water is sufficient to thoroughly irrigate fifteen acres planted with a variety of crops, if none of them require very large quantities of water during short periods of time.

Mr. Coe has not been able to accurately estimate the profits obtained from irrigation, as the crops grown are used very largely for home consumption. Those sold go to local markets, which are often overstocked, and prices do not average as high as in some other cities. Mr. Coe, however, seemed thoroughly convinced that great profits may be obtained from irrigation where the expense for getting the water on to the land is not too great.

IRRIGATION ON THE FARM OF E. C. WARNER, NORTH HAVEN.

Mr. Warner began his irrigation operations about ten years ago, and has used the water mainly for strawberries and raspberries. The cultivated fields are so located that part of them may be watered by flowage from a pond supplied by springs and a small stream. Others are on high ground and may be watered from tanks located on a hill near by. A ram is used for filling these tanks, the source of the water being numerous small springs, the water of which, having been conveyed to a common point, makes a pond of about half an acre in area. A fall of six feet is obtained from the pond to the ram, and the water is lifted sixty feet in height, a distance of 600 feet to the tanks. As this system is essentially the same as that on the farm of Mr. Eddy, which is fully described further on, no detailed description is necessary. The water is mainly used directly from pipes, being sprinkled on the crops by means of hose.

On the west side of Mr. Warner's farm a small stream flows through a pasture, and by building small earth dams and ditches, the water is conveyed into a pond located a few feet higher than one of the strawberry fields. The fall along the rows of strawberries is very slight most of the distance, and the water is conducted across the rows near one end and turned down the rows as needed. At one point in the field there is a knoll so high that the water cannot be gotten on to a small area, but it is conducted around the knoll and then flows readily along the rows again, and over the rest of the field. Although no attempt was made to estimate the differences in yield, the crop obtained from this knoll was very much smaller, and the fruit of much poorer quality than over the rest of the field. The plants also were so much injured by the effects of the drouth that when seen in September they presented a striking contrast to the plants only a few feet away where the water had been used. The yield on this knoll was estimated to be only one-third as much as it was over the rest of the field, and Mr. Warner thinks that the crop on the whole field was double what it would have been had no artificial watering been done. The entire expense represented only a few days' work with men and teams, probably costing less than $25, when estimated at market rates of labor. So great

were the benefits derived from this small effort that Mr. Warner at once set about making plans to enlarge his system; and the past fall (1895), he has built a large storage pond, a little higher up the stream, where he expects to have storage capacity and water sufficient for four or five acres, all of which can be watered by direct flowage.

Mr. Warner has obtained very beneficial results from irrigation on raspberries. He has also used it to advantage upon peach trees in times of severe drouth during the fruiting season.

IRRIGATION ON THE FARM OF HALE BROS., SOUTH GLASTONBURY.

The Hale Bros., of South Glastonbury, extensive growers of fruit and nursery stock, have long felt the importance of irrigation in their business, and have been for some time maturing plans for utilizing a supply of water near their farm. They have been delayed in getting unrestricted legal rights to the water, but during the fall of 1895 were able to obtain control of the necessary supply, and have been laying out one of the largest, if not the largest, system of irrigation to be found in this State.

A small brook, which has never been known to go dry, has been dammed, and thus a reservoir formed. The source of the water is about 5,000 feet distant from the fields to be irrigated, and the fall about 100 feet. Heavy cast-iron pipe six inches in diameter, jointed together with lead, are used for 360 feet from the reservoir, and then a 4-inch pipe for 1,900 feet, or until a fall of fifty feet is obtained, after which the size of the pipe is reduced to three inches. The pipe is carried along the top of the ridges of the farm, and at points about 200 feet apart hydrants are placed, so that the water can be taken from the main pipe and used for surface flowage or for sprinkling. It is believed that there is sufficient water to thoroughly irrigate from forty-five to fifty acres of land, mainly by surface irrigation. The contour of the land and the character of the soil are such that water can be distributed between the rows of plants and trees, so as to give a very even distribution.

The Hale Bros. propose to use the water on small fruits, and ultimately on peaches. Mr. J. H. Hale is thoroughly convinced that the use of water on peach trees will prove profitable during

the fruiting time in seasons of severe drouth. An observation that he made several years ago may be of value as indicating the importance of a good water supply for this crop. At this particular time Mr. Hale had two large orchards, one on the home farm, and one about two miles away, both being upon soils of rather dry character. Shortly before the picking season began he made an estimate of the fruit that he expected to get from the two orchards. Very shortly after a severe thunder storm with drenching rains occurred at one of the orchards, but no rain fell at the other. Otherwise, the season was generally dry. At the end of the harvest he found that his estimate for the two orchards was just reversed in the crop actually obtained. In other words, the crop on the orchard which received the heavy rainfall was just about double the estimate, while the crop on the other orchard fell off one-half from the estimate.

IRRIGATION ON THE FARM OF JOSEPH ALBISTON, SOUTH MANCHESTER.

Mr. Albiston probably has the oldest irrigation plant in Connecticut. The privilege was granted in 1796, the water being taken from a small stream at a point about sixty rods above the limits of the farm. The stream is of sufficient size to about fill a 10 or 12-inch pipe in times of an average flow. The brook passes through part of the farm, and about seven acres of land either side of the stream can be watered. There are two small irrigation plants now in use on the farm. In the older the water is conveyed in an open ditch. The fall of the stream is such that at a very small expense for a dam practically all of the water can be turned into the ditch. About five acres can be watered by this means. This plant was very extensively used in irrigating grass for many years, fine crops being obtained each season, but during the past sixteen years Mr. Albiston has used it for small fruits and vegetables. Of the area watered from the canal, about three acres are nearly level, having a fall of less than five feet in 400 feet. The water can be conveyed by a branch ditch along one end of this area and then turned down between the rows of small fruits and vegetables as needed. About one acre, on quite a steep slope just below the main ditch, is thoroughly watered by seepage

from the canal, the water percolating through the soil a few feet below the surface for a distance of about four rods. This is a very peculiar and unusual condition, and cannot well be accounted for. It may be due to a hardpan bottom, which slopes nearly uniformly in the same direction as the surface.

A second plan of irrigation was adopted for a part of the farm a few years ago. At a point near where the same brook just referred to enters the farm a dam and small pond were constructed. The water of this pond is now used in the irrigating about two acres of the bottom land along the brook.

Most of the soil of the irrigated area is a gravelly loam, much of which has been washed down from the surrounding hills. About two acres of the bottom lands are of a more compact soil with a hardpan subsoil. This area has been underdrained and much improved. The surplus water used in irrigation is now readily conveyed away through the under drains.

Mr. Albiston has found the use of irrigation especially profitable on strawberries. Since he has irrigated this crop he rarely ever fails to obtain large yields, while before irrigation was employed he says failures from drouth were a common thing. In 1894, thirty-two square rods of land planted with Crescent strawberries produced at the rate of 10,400 quarts per acre. In 1895, with a very severe drouth in strawberry time, Mr. Albiston claims that his crop was the best that he ever produced. The black-cap raspberries and blackberries have each year produced exceptionally fine crops under irrigation. Potatoes have been irrigated during seasons of drouth. In 1894, which was an exceptionally unfavorable season for potatoes, the crop obtained by irrigation yielded at the rate of 300 bushels to the acre. Mr. Albiston is especially fortunate in being able to irrigate on quite an extended scale at a very small cost. Under conditions of this kind irrigation must pay a very fine profit.

IRRIGATION ON THE FARM OF JOHN LEEK, OF HAMDEN.

On this farm about five acres are under irrigation at the present time. The land is low, nearly level, lying between the slopes of hills, with a small stream of water passing through the irrigated area near the centre. The surface soil is a fine, gravelly loam that has apparently been washed in

from the surrounding hills. At a depth of about three feet is a gravelly clay hardpan, beneath which is a stiff clay. The land is naturally quite fertile, but a compact subsoil has prevented the escape of surplus water, while in case of drouths the land has baked and cracked badly. The physical condition of the soil has been greatly improved by drainage, and in case an excess of water is used in irrigating it will also readily pass off through the drain pipes. The texture of the soil is firm enough to prevent washing, and the fall is about three feet to one hundred, so the conditions are favorable for surface flowage from open ditches.

A small stream of water that would, in times of an average flow, readily pass through a 5-inch pipe, enters the farm through a narrow ravine and makes a fall of about twenty-five feet for the first thirty rods back from the irrigated area. About fifteen rods up this ravine has been built a dam and a small storage pond, from which the water is conveyed in open ditches to different parts of the field. The whole area has been laid out in three lots in such a way that water can be conveyed to the ends of the fields and allowed to run down between the rows of crops. The water has, in a small way, been used on a variety of garden crops, but quite extensively on strawberries and celery. Mr. Leek is so well pleased with the results on these crops that he is planning to enlarge his storage pond and to use the water more extensively in the future.

The conditions on this farm are similar to those found on many Connecticut farms, in that the water can be obtained for irrigation at a nominal cost. There are farms all through the State through which pass small streams having their source on higher ground near by, and all that is necessary to utilize the water is to build a storage pond and carry the water from this, by means of open ditches, to the lands to be irrigated.

IRRIGATION ON THE FARM OF W. A. LEIGH, THOMASTON.

This farm is located in the Naugatuck Valley, at the base of a bluff that rises, quite abruptly, some 350 feet above the valley. Over this bluff pours a small mountain stream that is quite constant, and of volume about sufficient to fill a 6-inch pipe in times of average flow. This stream is fed by springs

near the top of the bluff. By building a dam across a narrow ravine, 300 feet above the irrigated fields, a storage pond covering about five acres was formed. The water is conducted through a 3-inch pipe laid on the surface of the ground, and is used in furnishing power for a small granite works as well as for irrigating. The pressure is so great—about 125 pounds to the square inch—that a small stream runs a water-wheel furnishing seven horse-power. The water is mainly used at night for irrigating purposes.

For watering purposes, branch lines of respectively one and a-half and one-inch diameter pipe are laid on the surface of the ground some fifty feet apart. Short pieces of hose are attached to the line of pipe once in about fifty feet, and the water is applied by spraying through a ⅜-inch nozzle. The pressure is so great that three or four of these ⅜-inch streams may be kept "playing" from a single line of pipe at the same time. The water is forced to a great height and spreads over a large area, like a lively shower.

While Mr. Leigh has about eighteen acres upon which irrigation might be applied, its use has been confined to strawberries. Beginning in 1887, he has irrigated this crop every year since. In 1895 about three acres were under irrigation. The water is first applied about the time the plants bloom, and is continued till near the end of the fruiting season, if needed. Mr. Leigh prefers to use the water largely at night, as he claims it blackens or blights the leaves if applied near the middle of the day when the sun shines brightly. No accurate comparisons as to the yields with and without irrigation have been made, but Mr. Leigh estimates that double the crop has been obtained as a result of the free use of water.

IRRIGATION ON THE FARM OF J. C. EDDY, SIMSBURY.

Mr. Eddy is making a specialty of small fruits and vegetables, and the severe drouths which have occurred each summer for the past three or four years have forced upon his attention the importance, for the financial success of his business, of an abundance of water. The farm is located near the western limits of the Connecticut Valley, and is composed mainly of a light, porous, rather sandy soil that requires large quantities of water to grow crops successfully. A small stream,

within a narrow valley, passes through the farm, and the tillable lands lie mainly upon slopes just outside this valley. The water of the stream is not very cold, and the temperature is raised somewhat by allowing the water to stand in a storage pond, where a large surface is exposed to the direct rays of the sun. The water appears to contain quite a little organic matter, and doubtless furnishes considerable plant-food in addition to the direct effects of the water.

It was found impossible to get the water to other than a small portion of the farm by damming the stream and building ditches; and it would have cost quite a sum even then to have secured the "right of way," as the water would have had to be taken from a point beyond the limits of the farm. Some form of pumping appliance seemed to be the only feasible means of making the water available for irrigation, and a ram was adopted as the most practicable. In order to get the necessary fall for "running" the ram, a canal about forty rods in length was dug along the outer edge of the valley. From the lower end of this canal the water makes a fall of seven feet, through a 6-inch drive-pipe, and operates a large ram located near the centre of the valley. The water is turned into the canal by a small and inexpensive wooden dam. No more water is allowed to enter the canal than can be carried off through the drive-pipe of the ram. The supply that flows in the brook is many times the amount that even the heaviest form of ram could lift.

At quite an elevation above the cultivated fields, on soil of a heavy, clayey nature, was a small pond that usually became dry in summer. This was enlarged by dredging, and by building an earth dam on two sides. A storage pond was thus provided with an area of about half an acre and an average depth of about four feet, with a bottom tight enough to prevent much soakage. This pond is located about eighty rods from the stream, at the nearest point, and high enough to give good fall to most of the cultivated fields. The water has to be lifted to a height of seventy feet before it enters the storage pond. Connections can be made with this pipe at various points between the ram and the storage pond, and the water be thus used directly for irrigating certain areas. The main pipe used is two and one-half inches in diameter, and is laid

only sufficiently deep, so as not to interfere with cultivation. Mr. Eddy has been so successful in his operations during the past year that he proposes to enlarge his plant and to force the water over a large area of land on the opposite side of the valley from the storage pond. The contour lines show the amount of fall from the storage pond. The experiment plots the past two years are indicated by Ex. '95 and Ex. '96. The accompanying diagram will give a clear idea of the position of the ram, storage pond, and the various fields that can be watered.

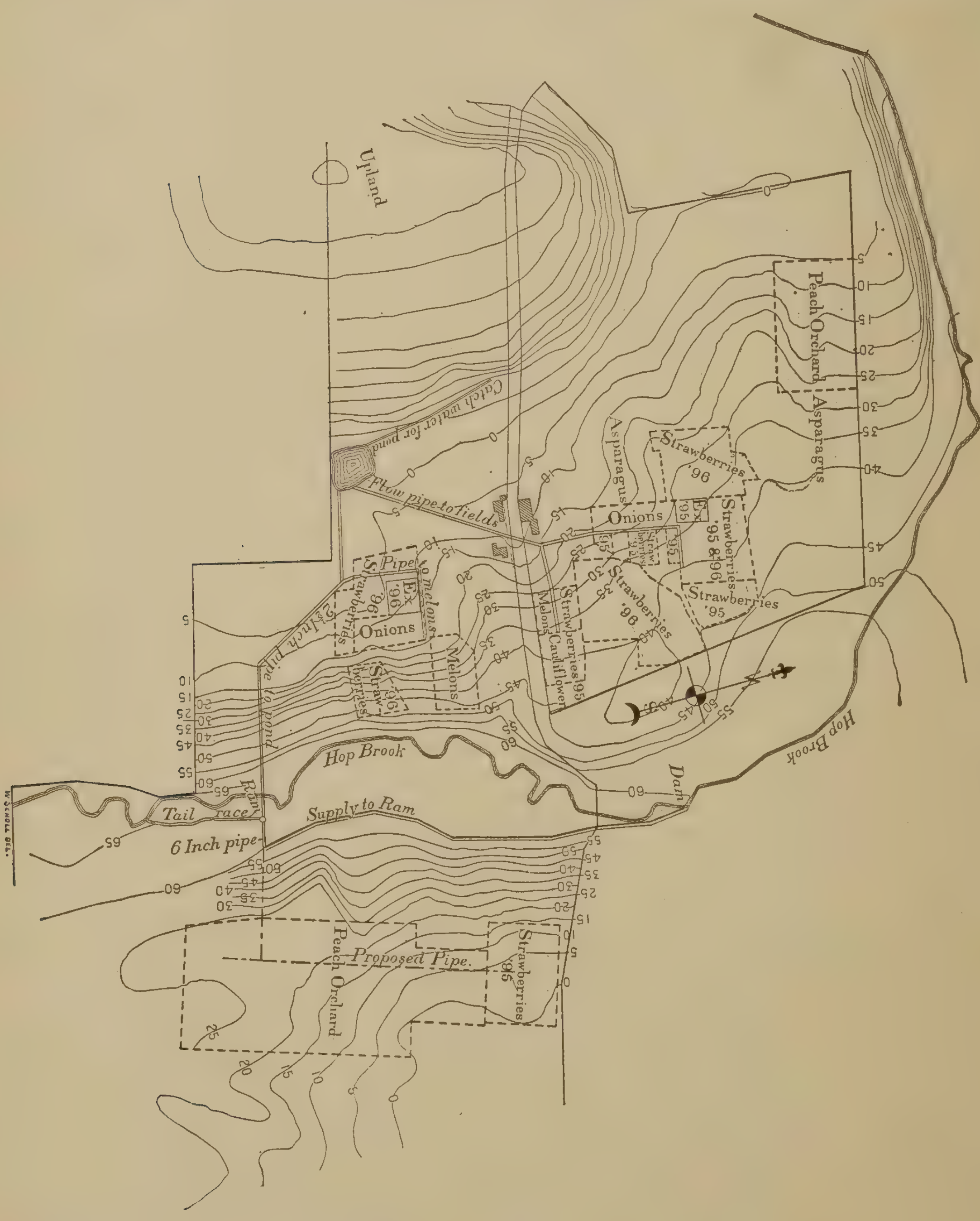


DIAGRAM OF THE FARM OF MR. J. C. EDDY, SIMSBURY, CONN.

(Published through the courtesy of the Office of Experiment Stations, U. S. Department of Agriculture.)

The fields to the north of the farm buildings are watered through pipes directly from the storage pond. Some difficulty has been experienced in getting a good flow, because air accumulated in the pipes where these ran over a slight elevation. By changing the course of the pipes a little Mr. Eddy found that he could avoid this difficulty and get a constant fall. The air might also be allowed to escape, under such conditions, by having a small petcock placed in the pipe at the highest point. Two acres of strawberries on the north side, which were irrigated during the season of 1895, were on land of such slope that either surface flowage or sprinkling could be used.

CROPS GROWN BY IRRIGATION ON FARM OF J. C. EDDY, SIMSBURY.

Strawberries, muskmelons, onions, and cauliflower were successfully grown by irrigation, by Mr. Eddy, during the past year (1895). These have proved especially important crops, because of their high value per acre, and the fact that the farm being located at quite a distance from markets, bulky crops giving smaller profits per acre would be expensive in handling. The variety of crops grown did not necessitate water in very heavy quantities at any one time during the season, unless, perhaps, for a few days during the fruiting season of the strawberries.

RESULTS OF IRRIGATION ON STRAWBERRIES.

Mr. Eddy had four acres of strawberries in 1895. Two of these were located on high ground at the east side of the farm, and could not be irrigated, and the other two on quite low ground north of the buildings to which pipes were laid for the water. A severe frost in May appeared to have destroyed many of the blossoms, and lessened the crop prospects very decidedly for the two acres located on low ground, while but little damage resulted to those on the high ground. Owing to this condition Mr. Eddy had expected to get larger returns from the field located on high ground, provided rainfall had been abundant. As it was, however, a drouth began early in June and seriously reduced the strawberry crop all over the State. At the end of the season Mr. Eddy found that the two acres which were not irrigated gave a yield of 150 crates (32 quarts each), while the two acres that

were irrigated yielded 415 crates. After the first few days picking the fruit on the non-irrigated field was much smaller and darker colored, and averaged only about eight cents a quart for the season, while that from the irrigated field averaged eleven cents a quart. It must be remembered, however, that the fruit from the non-irrigated field had to be sold when the markets were heavily stocked with berries, while much of that from the irrigated area reached the market after prices had risen, owing to the general shortage from the effects of the drouth.

The water was not applied until just before the picking season opened, although Mr. Eddy thinks better results would have been obtained had he begun to use the water two weeks earlier. The method of applying first adopted was surface flowage, but owing to the mulch between the rows it was found that this method was a very slow one. The mulch impeded the movement of the water, and often changed its course from between the two rows where the flow was started. For these reasons the plan of sprinkling from hose was adopted. Condemned 2-inch fire hose, with a large sprinkler, was used; this threw a powerful spray, covering an area about twenty feet in diameter. The pressure was sufficient to give a flow of thirty gallons per minute, with which it was found that one man could thoroughly water an acre in about ten hours. Later experience has shown that it is better to remove the mulch and allow the water to flow between the rows before the picking season opens, and then to replace the mulch if necessary.

RESULTS ON MUSKMELONS.

When grown on light soil and forced along rapidly early in the season, muskmelons have generally proved a very valuable crop in this State. Much loss, however, has been occasioned by frosts before considerable of the fruit was in condition to market. Mr. Eddy has found that by irrigating he has been able to get the melons into market considerably earlier than usual, and to get large crops before killing frosts come. As the plants only cover a small portion of the ground early in the season sprinkling seems to be the best method of applying the water, and where the soil is loose and porous, with considerable fall, sprinkling is, without doubt, the best method for

the entire season. By applying water once in five or six days, when a lack of rainfall seemed to make it necessary, Mr. Eddy finds he has been able to cause steady growth of the vines and to get a much larger yield than could have been obtained without artificial watering. There was much complaint as to the general quality of the fruit of muskmelons in the market in 1895, but Mr. Eddy says the flavor of his fruit was better than ever before, as attested by many of his customers. This may be a valuable feature of irrigation upon this crop; however, further experimenting will be necessary to establish this fact. The melon crop grown upon one acre by irrigation sold for $350, and the vines were "full of fruit" when they were killed by frost September 14.

ONIONS.

This crop did not suffer materially from drouth during 1895 in this State. Mr. Eddy's crop, however, was grown upon very light soil, and he had the ground thoroughly sprinkled once during the growing season. A small portion of the field could not be reached with the hose, and this was allowed to go without artificial watering. No measurements of the crop were made, but when visited by the writer, while the crop was being harvested, considerable difference could be seen between the crop on the irrigated land and that on the small strip which was not irrigated. One thing especially noticeable in addition to the smaller yield was the increased proportion of small onions where no water had been used.

CAULIFLOWER.

About one acre of this crop was grown during 1895. The crop was grown on a field of medium heavy loam only a few feet above the bottom lands of the valley. The fall across the field, lengthwise of the rows, was at the rate of three feet per hundred. From a 2½-inch pipe, with a 2-inch hose, about forty gallons of water per minute could be obtained, and only about eleven minutes were required for the water to flow from one end of the rows to the other, a distance of 175 feet. The water was applied once in about five or six days, if the lack of rainfall seemed to make it necessary. The cauliflower headed earlier than usual in 1895, and the crop sold readily at about $400 per acre.

EXPERIMENTS ON THE EFFECT OF IRRIGATION ON STRAWBERRIES.

In June, 1895, the Station began some experiments on the farm of Mr. J. C. Eddy, for the purpose of studying the effects of irrigation on the quantity and quality of strawberries, and to ascertain some facts regarding the profits to be obtained from the use of irrigation.

It is hoped that this will prove the beginning of a series of experiments in this State on the effects of irrigation on a variety of crops. There are many questions that it seems desirable to investigate in connection with the subject, such as the different methods of applying water and the relative advantage of each, observations on soil temperature, determinations of the amount of plant food supplied in the water used, and chemical analyses of fruits for the purpose of determining the amounts of sugar where the crop is irrigated or not irrigated. The work was undertaken so late in the season that observations were made only on the yield, and on the quality of the crop, as indicated by taste and appearance.

PLAN OF THE EXPERIMENT.

A section of about two acres was chosen from a field of strawberries. The soil appeared to be nearly uniform, and the conditions were favorable for applying the water. The field had been set to strawberries in the spring of 1894. The "Haverland" was the variety used, with every fourth plant in the row a "Jessie," the latter being used for fertilizing. The plots were laid out 115 feet long and twelve feet wide, three rows to a plot; two plots being irrigated and two not. Two rows were left between plots, which were not included in the experiment, in order to thoroughly separate the irrigated from the non-irrigated sections. The plots were to be irrigated as often as seemed to be necessary to get good commercial results.

RESULTS.

The following table gives the yields in quarts and pounds for each day when fruit was picked. The picking, by a representative of the Station, was done as often as seemed necessary to have the fruit in good marketable condition.

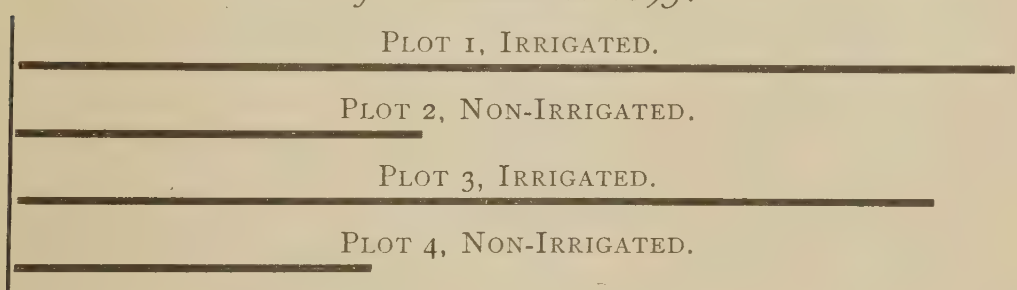
TABLE 71.

Irrigation on strawberries. Yields on irrigated and non-irrigated plots.

Date.	Plot 1, Irrigated.		Plot 2, Non-Irrigated.		Plot 3, Irrigated.		Plot 4, Non-Irrigated.		When Watered.
1895.	Qts.	Lbs.	Qts.	Lbs.	Qts.	Lbs.	Qts.	Lbs.	
June 13,	1.1	1.6*	4.0	5.6*	3.9	5.5*	3.0	4.2*	Watered June 10.
June 14,	4.0	6.0*	6.0	8.4*	4.0	5.6*	6.0	8.4*	
June 15,	12.0	18.0*	12.0	16.8*	13.0	18.2*	6.5	9.1*	Watered.
June 17,	19.5	29.1	18.0	25.6	25.0	34.8	18.0	24.9	
June 18,	14.0	19.1	6.0	8.0	14.0	17.9	3.5	4.9	Watered.
June 19,	14.0	19.1	5.0	6.5	17.0	23.2	4.5	6.5	
June 20,	21.0	27.8	3.0	4.0	12.0	15.7	3.0	4.3	Watered part in eve. of 20th, balance early A. M. 21st.
June 21,	16.8	22.2	3.0	3.2	11.8	14.8	3.0	3.6	
June 22,	10.0	12.4	3.0	4.4	6.0	7.4	5.0	5.1	
June 24,	25.0	34.0	4.5	5.3	(†)	(†)	(†)	(†)	
June 25,	6.0‡	8.4‡	‡1.5	1.8	32.0	42.7	5.0	6.8	
June 26,	14.0	20.8	1.3	1.7	7.0	10.1	2.0	3.0	
June 27,	9.0	12.2	1.0	1.0	3.5	4.7	1.0	1.0	
June 28,	—	—	—	—	—	—	—	—	Rainy.
June 29,	4.0	5.5	1.0	1.1	3.5	4.9	1.0	1.4	
July 2,	5.5	7.9	0.5	0.8	6.0	8.3	0.5	0.9	
July 5,	2.0	2.4	—	—	1.0	1.4	—	—	
Total,	176.9	246.5	69.8	94.2	159.7	215.2	62.0	84.1	

* Assumed to weigh same rate per quart as on June 17.
† Not picked. ‡ Not all picked.

Comparative yields in quarts on irrigated and non-irrigated plots of strawberries 1895.



The yield on the two irrigated plots was at the rate of 5,318 quarts per acre; and on the two non-irrigated, at the rate of 2,083 quarts.

Water was used on the irrigated plots on June 10, 15, 18, and 20. The water was applied by means of 2-inch hose from a 2½-inch iron pipe laid on the surface of the ground. The size of the stream and the force of the water was sufficient to give thirty gallons (about one barrel) per minute. At this rate of flow one man could sprinkle about one acre per day. The ground was given a thorough wetting each time.

There was very little rainfall during the first twenty-five days of June. Seven-tenths of an inch fell between the 2d and 6th, but from the 6th to the 22d no rain whatever fell. On the 22d there was .25 inches, and after the 25th of the month rain was quite abundant. Strawberries, generally, began to feel the effects of the drouth by June 17th, before the picking season was more than one-third through.

It will be noticed that for the first two pickings the results were in favor of the non-irrigated plots, and that the yields on the non-irrigated plots were nearly as great as on the irrigated until after June 17. For the second picking (June 14), the two watered plots only gave eight quarts while the two not watered yielded twelve quarts. This tends to show that irrigation retards the development of the fruit and causes it to ripen a little later. Mr. Eddy noticed this same condition on his larger fields. During the first few pickings the fruit from the non-watered plots was noticed to be sweeter, but that from the watered plots were larger and "looked three cents per quart better."

On June 17th the leaves of the plants on the non-watered plots began to wilt quite badly and the berries to shrivel, and by the 18th the leaves were so dry as to break off, and the unripe fruit to shrivel and stop growing. The plants on the unwatered plots continued to dry, the leaves began to fall, and the fruit was small, dark colored, shriveled, and seedy.

On June 24th the writer visited the fields and made the following notes: "Plants on non-irrigated plots are drying badly. Leaves shriveled, and many dry and dead. Fruit small, dark colored when ripe, and shriveled and seedy. Hulls shriveled. Fruit looks over-ripe when picked. The darker color is probably due to the increased sunlight that the fruit gets, owing to the shriveled condition of the plants."

"Plants on the irrigated plots look fresh and vigorous; fruit large and abundant; much green fruit continuing to develop. Size of berries large, color bright. Fruit not quite as sweet as on the non-irrigated plots. Should judge the fruit from irrigated plots would sell for two to three cents per quart more than that from non-irrigated."

Mr. Eddy found that the fruit from the non-irrigated plots had to be sold for an average of nine cents per quart while that

from the irrigated areas brought eleven cents. At these rates per quart the fruit on the irrigated plots sold at the rate of $584.76 per acre, and that on the non-irrigated at the rate of $187.47 per acre, a difference of $397.29 per acre in favor of irrigation.

It will be readily seen that even with two acres of strawberries the increased returns obtained by the use of water would furnish quite a sum toward covering the expense of an irrigation plant.

SUGGESTIONS REGARDING IRRIGATION.

The contour of most of the land of Connecticut, and, in fact, of all New England, is such as to readily admit of the conveyance and application of water for irrigation. Streams, ponds, and springs are common and, except in cases of severe drouths, furnish an adequate supply of water. Many crops like strawberries, raspberries, and early vegetables need irrigating, if at all, early in the season, when the supply of water is often sufficient, while, perhaps, later in the season it would not be. Much of the land that would be improved by irrigation is in valleys, close to streams and ponds, which in many cases are high enough to give a moderate flow on the areas below, so the cost of getting the water would be merely nominal. The soils used for our most profitable crops are generally light and porous and leach water readily, but are just the kind that most need irrigating; while our best money crops, such as small fruits and vegetables, are heavy users of water. There is no need of drainage in connection with irrigation on soils of this class as is often the case where the surface soil is compact.

SOURCES OF WATER AND MEANS OF MAKING IT AVAILABLE.

The sources of water for irrigation in Connecticut are natural or artificial ponds, streams, and springs, and in some cases wells. In many cases ponds are so located that water can be conveyed from them to fields on lower ground by means of open ditches, the expense depending upon the distance and the character of the ground to be passed through. This is often the cheapest method for securing water. When the supply is large the loss of water occasioned by soakage from the ditch or evaporation is not of serious consequence. The fall of many of our small streams is so great that by building a small dam

the water may be turned from its natural course and conveyed in ditches along the outer edge of the valley and then allowed to flow over the surface of the fields back of the natural stream. A number of instances have come to our notice where the light alluvial soil of our valleys might thus be watered at small expense. In many cases the water could be taken from an old mill site and would be found sufficiently high to use for irrigation after it leaves the water-wheel. The water from several springs may some times be conveyed to a single point and then held in a small pond and the water drawn from this as needed. Where only small areas are to be irrigated wells may be made a source of water supply. The well must afford a large flow and should be so located that the water can be stored at some point at least twenty-five feet above the fields to be watered. In many cases bored wells might be utilized and afford a heavy flow of water.

PUMPING APPLIANCES.

Rams.—In many places in Connecticut the source of supply is below the fields to be irrigated and the water can only be made available by some pumping device. The cheapest sources of power are water and wind, although steam and electricity may be profitably used where the water is wanted only for a short period. A ram, under many conditions, is the best power. As only a small part of the water that is needed to operate the ram can be pumped, the supply must be quite large and the ram of heavy capacity. If the water is lifted over forty or fifty feet high the strain on the ram is quite severe and all the parts must be securely and strongly made. But few styles of rams manufactured in this country are powerful enough to supply water for anything but small areas (four to eight acres).

Windmills.—If wind is the form of power to be used the mill should be constructed of the best material, and be strong and secure in all its parts. Cheap forms of mills should be avoided in all cases. The best steel mills are the cheapest in the end. The mill should be located on high ground so it will "catch" the wind from all directions and so the place of storage may be sufficiently above the fields to be irrigated to give a good fall. The average velocity of the wind in New England is about twelve miles per hour. A 14-foot wheel will

do good work with a wind of ten to fifteen miles per hour. Of course the movement of the wind is very irregular, but there is usually sufficient to afford power to supply water for five to eight acres, by having a large storage tank. Wheels of large diameter are to be preferred in order to utilize light breezes.

Steam power.—When water is wanted for a short time on one or two crops which generally give good profits, some form of engine and pump may be economically used. The Wisconsin Experiment Station has watered a variety of crops in this way and has shown this method of irrigation to be a profitable one. By the use of a No. 4 Rotary Pump, driven by an 8-horse portable farm engine, Prof. King of that Station writes* that he has "drawn water through 110 feet of 6-inch suction pipe, raising the water to a height of 26 feet at the rate of 80,320 cubic feet per ton of soft coal, which is equivalent to 22½ inches of water per acre or over 7 acres covered to a depth of 3 inches. But this amount is much less than would have been moved with the same fuel had the pump been provided with a larger discharge and could the water have been used as rapidly as pumped so as to have made frequent stops unnecessary." For crops like strawberries, raspberries, and some vegetables which give large returns per acre and require water only for short periods of time, steam may be economically used as a source of power for pumping. On many farms a portable engine might be profitably rented for a few weeks during the strawberry season. This is a time when farm engines are seldom wanted for other purposes. Naphtha or gasoline engines of five to six horse-power are economical of fuel, can be easily operated, are of lighter weight than coal engines, and as a source of power they are worthy of careful consideration.

Electricity.—The recent wonderful developments in electricity point to that as one of our cheapest sources of power. Where such power is convenient we believe it can be economically used for pumping water for use on small fruits and some vegetables.

THE STORAGE OF WATER.

When the source of the water is below the fields to be irrigated some means of storage must be provided on high ground.

* "The Soil," page 274.

This may also be necessary in order to provide greater pressure, in cases where streams are utilized. If the supply of water is limited it will be found necessary to prevent waste as far as possible. This can best be done by storing the water in a tank or cemented reservoir, where but little evaporation and no loss by soakage can take place. If tanks are used they must be strongly built and of large capacity. Tanks of 15,000 to 20,000 gallons capacity are needed to supply water for five or six acres planted to a variety of crops.

Reservoirs.—Where large quantities of water are to be stored the open reservoir is the only practicable plan. If this is used in connection with some pumping appliance the losses by soakage and evaporation may be of serious consequence. These losses may be reduced if the bottom is of clay and the banks are so constructed as to avoid soakage. Loss by evaporation may be lessened by having the surface area small, while the desired capacity may be gotten by having a greater depth.

DISTRIBUTION AND APPLICATION OF WATER.

The oldest and most common method of distributing the water over the fields to be irrigated is by means of small ditches. These can be made by turning a furrow with a plow along the highest part of the field to be watered. By having a number of lines of these ditches parallel to each other along the slopes of the land the water may be let out on the lower side of the highest ditch and distributed over the land between this and the next ditch, while the second ditch will catch the surplus water. A man with a hoe removes obstructions and directs the water by opening small water courses. With a little attention the water can be made to touch nearly all parts of the field.

For crops like strawberries, when the water must be run between the rows, these should extend up and down the slope. Only a slight slope is needed to give free movement to the water; from three to six feet for every one hundred feet is better than a greater fall. With a heavy fall, and especially if the soil is sandy, serious washing will often result. In case mulch is used on strawberries it is found to interfere badly with the flow when the water is applied by surface flowage. If mulch is thought to be necessary to keep the fruit clean,

water should be applied freely just before the picking season begins and then the mulch applied. Prof. E. S. Goff, of the Wisconsin Experiment Station, has successfully used wooden troughs for distributing the water. These are made of rough boards ten and twelve inches wide, nailed together V-shaped, and are supported on stakes across the upper ends of the rows in such a way as to give a slight fall across the field. By means of small auger holes the water can be made to flow out between the rows. With small strips of tin, gates are made over these holes so that the amount of flow can be regulated.

If the water supply is limited iron pipes may advantageously be used in distributing the water to the points where needed. The water may either be allowed to flow from these over the surface or be applied by sprinkling. Unless the fall is very great (100 feet or more) these pipes should be at least two inches in diameter. If the distance is great and the fall does not exceed 100 feet there will be a serious loss of power by friction in case small pipes are used. Condemned fire hose two to three inches in diameter can be bought in most of our large cities, and if the fall from the reservoir or tank is fifty feet or more a heavy spray can be obtained by their use. A flow of twenty-five to forty gallons per minute seems to be necessary in using iron pipes and hose, in order to apply the water as rapidly as is desirable for strawberries.

In case a fall of 200 to 300 feet can be obtained, and the water can be conducted in pipes, it may be applied by means of lines of perforated pipes laid on wires over the fields. By this method very little labor is necessary as the water can be turned from one line of pipe into the next at pleasure. This method of irrigating strawberries was successfully carried on for a number of years by Dr. J. B. Learned, of Florence, Mass. The source of the water was the aqueduct supply of the town. Later the project had to be given up because the town needed all of the water for household and manufacturing purposes.

DIGESTION EXPERIMENTS WITH SHEEP.

BY C. S. PHELPS AND A. P. BRYANT.

One of the most important factors in the study of the laws of animal nutrition is the digestibility of the food. Only that portion of the food which is actually digested by the animal can be used for nutriment. Chemical analysis alone does not tell the nutritive value of the food, but the chemical composition taken in connection with actual digestion tests indicates quite accurately what portion of the food may be available for the nutrition of the animal. From experiments made elsewhere it has been found that differences of age, breed, and species of ruminants make comparatively slight differences in the proportions they digest from any given material. The digestibility of a feed by a sheep can be taken as a tolerably correct measure of its digestibility by a cow or steer. As sheep are easier to experiment with than the larger animals, and as many of the feeding experiments by the Station are with sheep, they have been employed in the digestion experiments which are here reported upon.

In order to learn more of the digestibility of feeding stuffs, and because of the need of digestion factors for use in connection with feeding experiments, the Station began in 1894 a series of digestion experiments with sheep. For a description of the method of conducting these experiments the reader is referred to the Annual Report of the Station for 1894, pages 107–109. It will suffice to say here that the feeding stuffs, the uneaten residues, and the feces were weighed and analyzed, and the differences between the amounts of organic matter and nutrients in the food eaten and in the feces were taken as the measure of the amounts digested. The sheep were kept in pens about five feet square, with mangers so arranged as to prevent loss of food by scattering. The feces were collected in rubber-lined bags. Each experiment lasted twelve days. The first

seven days were devoted to preliminary feeding, during which the feces were not collected and each animal had the run of its pen. At the end of the first seven days the sheep were placed in a narrow stall where they remained during the five days of the digestion experiment proper. In these experiments, as in those with men, the metabolic products in the feces are counted as if they were part of the undigested residue of the food. The heats of combustion of the food and feces were determined by the bomb calorimeter, and the results taken as the measure of the fuel value. The nitrogenous matter of the digested food is not completely oxidized in the body, but a portion is eliminated with the urine in urea and kindred compounds. The potential energy of these compounds does not become available to the body. Its amount is roughly calculated in the manner described on page 178, in the discussion under digestion experiments with men. The assumptions there made probably give rather too low results. Late research seems to indicate that a larger factor should be assigned for the fuel value of the nitrogenous matter of the urine. This subject is now being studied by the Station. Meanwhile the values here given may be considered as approximately correct.

General conclusions from these experiments will hardly be possible until more data are available. One point is, however, brought out very clearly. Among the feeding stuffs tested, those rich in protein, such as the legumes, are much more digestible than those with little protein, such as corn fodder, oat fodder, millet, and the like.

Table 72, which immediately follows, gives a summary of the results obtained in the digestion experiments thus far made with sheep by the Station. These experiments are arranged, according to the character of the feeding stuffs used, under the headings: milling products (with hay), cured fodders and hays, and green fodders and grasses. The details of experiments Nos. 1–9 will be found in the Annual Report for 1894, and Nos. 10–27 in the Report for 1895. The detailed account of the other experiments (Nos. 28–45) follow the summary table.

TABLE 72.

SUMMARY OF RESULTS OF DIGESTION EXPERIMENTS WITH SHEEP.

Percentages of total nutrients and of fuel value of nutrients actually digested.

FEEDING STUFFS.	Expt. No.	Sheep.	Protein. N. × 6.25.	Fat.	Nit.-free Extract.	Fiber.	Ash.	Organic Matter.	Fuel Value.
Milling Products (with Hay).			%	%	%	%	%	%	%
Bran, corn meal and hay,*	1	B	48.0	60.6	71.5	45.6	5.9	62.7	57.6
Bran, corn meal and hay,	1	D	62.1	72.9	76.1	59.6	26.6	70.8	66.4
Bran, corn meal and hay,	4	B	57.6	69.1	80.1	60.7	32.0	72.8	67.9
Bran, corn meal and hay,	4	D	52.2	71.2	77.7	55.2	27.4	69.6	65.2
Average,	—	—	**55.0**	**68.5**	**76.4**	**55.3**	**23.0**	**69.0**	**64.3**
Bran, corn meal, linseed meal, oat and pea meal and hay,†	2	B	73.5	64.7	73.8	59.0	26.8	70.1	63.6
	2	D	71.2	71.2	74.9	60.8	28.2	70.9	64.8
Bran, corn meal, linseed meal, oat and pea meal and hay,	3	B	77.1	72.8	77.0	69.2	40.9	75.0	70.3
	3	D	71.6	73.4	73.6	61.1	20.9	70.3	65.4
Average,	—	—	**73.4**	**70.5**	**74.8**	**62.5**	**29.2**	**71.6**	**66.0**
Soy bean meal and timothy hay,	12	A	75.8	71.1	66.7	61.2	42.0	68.5	62.9
Soy bean meal and timothy hay,	12	B	77.0	76.7	69.0	61.2	51.6	70.5	65.9
Soy bean meal and timothy hay,	12	C	80.0	77.4	68.4	63.1	48.9	71.5	67.0
Soy bean meal and timothy hay,	12	E	76.0	71.4	60.9	56.7	51.1	65.4	61.3
Average,	—	—	**77.2**	**74.2**	**66.3**	**60.6**	**48.4**	**69.0**	**64.3**
Soy bean meal and timothy hay,	13	A	77.0	74.1	62.2	59.7	52.0	67.0	62.8
Soy bean meal and timothy hay,	13	B	77.4	73.3	66.5	63.1	36.8	69.5	64.0
Soy bean meal and timothy hay,	13	C	78.5	72.0	63.5	55.8	45.3	66.9	62.7
Soy bean meal and timothy hay,	13	E	80.0	73.1	71.8	69.5	48.6	73.7	68.7
Average,	—	—	**78.2**	**73.1**	**66.0**	**62.0**	**45.7**	**69.3**	**64.6**
Experiment 12, calculated for digestibility of soy bean meal above average,	—	—	85.1	86.6	73.6	—	26.3	77.5	72.2
Experiment 13, calculated for digestibility of soy bean meal above average,	—	—	86.6	83.2	73.1	—	16.2	78.4	72.7
Average of experiments 12 and 13, eight tests, calculated for soy bean meal alone,	—	—	**85.8**	**84.9**	**73.4**	—	**21.3**	**78.0**	**72.5**
Coarse bran and rowen hay, mixed grasses,	32	A	70.3	62.1	65.2	44.7	31.6	62.0	57.0
Coarse bran and rowen hay, mixed grasses,	32	B	68.9	54.9	66.7	47.8	30.2	62.7	57.1
Coarse bran and rowen hay, mixed grasses,	32	C	71.5	66.0	69.4	56.4	33.5	67.1	62.4
Coarse bran and rowen hay, mixed grasses,	32	D	67.5	60.7	67.4	47.0	24.3	63.1	57.8
Average,	—	—	**69.6**	**60.9**	**67.2**	**49.0**	**29.9**	**63.7**	**58.6**
Experiment 32, calculated for digestibility of coarse bran, average,	—	—	**70.3**	**72.2**	**67.2**	**16.2**	**17.2**	**61.3**	**56.6**

* The wide ration of sheep feeding experiments, pp. 92-106, Report of 1894.

† The narrow ration of sheep feeding experiments, pp. 92-106, Report of 1894.

TABLE 72.—*(Continued.)*

FEEDING STUFFS.	Expt. No.	Sheep.	Protein. N. × 6.25.	Fat.	Nit.-free Extract.	Fiber.	Ash.	Organic Matter.	Fuel Value.
Milling Products (with Hay).			%	%	%	%	%	%	%
No. 2 wheat middlings and rowen hay, mixed grasses, -	33	A	73.9	71.7	71.0	54.4	41.7	68.5	63.9
No. 2 wheat middlings and rowen hay, mixed grasses, -	33	B	76.1	68.9	71.9	54.6	32.5	69.2	64.4
No. 2 wheat middlings and rowen hay, mixed grasses, -	33	C	70.9	71.7	73.0	54.3	28.8	69.1	63.7
No. 2 wheat middlings and rowen hay, mixed grasses, -	33	D	70.6	70.3	71.1	58.6	32.5	68.7	63.9
Average, - - - - -	—	—	**72.9**	**70.7**	**71.7**	**55.5**	**33.9**	**68.9**	**64.0**
Experiment 33, calculated for digestibility of No. 2 wheat middlings, average, - -	—	—	**75.7**	**88.8**	**75.6**	**30.2**	**25.0**	**71.3**	**67.3**
Cured Fodders and Hays.									
Rowen hay, mixed grasses, chiefly Kentucky blue grass,	8	A	70.1	50.5	67.7	66.2	54.8	66.7	60.9
	8	B	67.6	44.0	62.9	65.4	49.4	63.5	57.1
Rowen hay, mixed grasses, chiefly Kentucky blue grass,	8	C	70.2	45.6	62.6	66.1	55.5	64.1	58.1
	8	D	68.4	44.6	67.0	68.2	52.4	66.3	59.5
Average, - - - - -	—	—	**69.1**	**46.2**	**65.1**	**66.5**	**53.0**	**65.2**	**58.9**
Rowen hay, mostly timothy, -	9	A	66.1	50.8	64.9	65.2	50.8	64.4	59.3
Rowen hay, mostly timothy, -	9	B	69.4	48.2	60.9	62.0	74.6	62.0	58.6
Rowen hay, mostly timothy, -	9	C	68.2	48.7	63.5	65.2	53.2	64.1	58.3
Rowen hay, mostly timothy, -	9	D	68.3	50.3	64.3	73.4	46.9	67.2	60.9
Average, - - - - -	—	—	**68.0**	**49.5**	**63.4**	**66.5**	**56.4**	**64.4**	**59.3**
Rowen hay, mixed grasses, -	30	A	67.7	47.2	66.6	65.9	42.5	65.6	59.3
Rowen hay, mixed grasses, -	30	B	68.2	49.4	66.9	66.7	37.3	66.2	60.6
Rowen hay, mixed grasses, -	30	C	70.8	50.6	68.5	69.2	41.8	68.1	62.4
Rowen hay, mixed grasses, -	30	D	69.1	47.2	66.8	64.6	38.8	65.6	60.0
Average, - - - - -	—	—	**69.0**	**48.6**	**67.2**	**66.6**	**40.1**	**66.4**	**60.6**
Rowen hay, clover, field cured,	28	A	60.3	58.3	63.1	47.6	42.4	58.1	53.0
Rowen hay, clover, field cured,	28	B	65.1	60.4	64.1	50.7	45.8	60.5	54.5
Average, - - - - -	—	—	**62.7**	**59.4**	**63.6**	**49.1**	**44.1**	**59.3**	**53.8**
Rowen hay, clover, barn cured,	29	C	69.1	60.5	62.2	46.4	50.3	59.7	54.1
Rowen hay, clover, barn cured,	29	D	64.7	59.9	61.7	44.7	44.5	58.0	53.0
Average, - - - - -	—	—	**66.9**	**60.2**	**62.0**	**45.5**	**47.4**	**58.9**	**53.5**
Average field and barn cured (four tests), - - -	—	—	**64.8**	**59.8**	**62.8**	**47.4**	**45.7**	**59.1**	**53.7**
Scarlet clover hay, field cured,	10	A	67.8	49.2	59.4	39.8	48.4	52.9	48.3
Scarlet clover hay, field cured,	10	B	67.8	49.2	62.7	41.4	41.5	54.9	49.6
Scarlet clover hay, field cured,	10	C	68.9	45.9	57.3	46.4	46.8	54.8	50.3
Scarlet clover hay, field cured,	10	D	68.5	52.4	60.7	47.3	51.2	56.6	51.9
Average, - - - - -	—	—	**68.3**	**49.2**	**60.0**	**43.8**	**47.0**	**54.8**	**50.0**
Scarlet clover hay, barn cured,	11	A	67.2	32.8	59.8	47.0	45.6	56.2	50.0
Scarlet clover hay, barn cured,	11	B	67.6	29.5	61.6	48.9	47.2	57.6	51.6
Scarlet clover hay, barn cured,	11	C	73.2	42.3	63.9	42.8	49.7	57.8	52.1
Average, - - - - -	—	—	**69.3**	**34.9**	**61.8**	**46.2**	**47.5**	**57.2**	**51.2**
Average field and barn cured (seven tests), - - -	—	—	**68.7**	**43.0**	**60.8**	**44.8**	**47.2**	**55.8**	**50.5**

TABLE 72.—(*Continued.*)

FEEDING STUFFS.	Expt. No.	Sheep.	Protein. N. × 6.25.	Fat.	Nit.-free Extract.	Fiber.	Ash.	Organic Matter.	Fuel Value.
Cured Fodders and Hays.			%	%	%	%	%	%	%
Oat hay (early seed), - -	31	A	52.3	60.5	52.3	45.6	19.6	50.7	46.6
Oat hay (early seed), - -	31	B	53.9	62.1	51.3	42.0	42.1	49.2	45.5
Oat hay (early seed), - -	31	C	57.7	63.0	53.9	46.8	41.7	52.6	48.9
Oat hay (early seed), - -	31	D	52.7	62.0	50.5	39.4	34.8	47.9	44.1
Average, - - - - -	—	—	**53.3**	**61.3**	**51.6**	**43.5**	**34.6**	**50.1**	**46.3**
Green Fodders and Grasses.									
Scarlet clover fodder, - -	5	A	76.7	67.3	74.5	54.1	55.0	68.5	63.7
Scarlet clover fodder, - -	5	B	77.5	62.9	74.9	57.9	55.9	69.8	64.3
Scarlet clover fodder, - -	5	D	77.2	69.3	74.1	56.2	57.4	69.1	64.3
Average, - - - - -	—	—	**77.1**	**66.5**	**74.5**	**56.1**	**56.1**	**69.1**	**64.1**
Barley fodder, - - - -	6	A	69.3	61.2	69.3	49.0	49.7	62.2	57.8
Barley fodder, - - - -	6	B	71.4	63.1	76.3	63.6	62.2	70.7	66.4
Barley fodder, - - - -	26	B	73.1	56.3	69.3	66.4	53.2	68.7	62.8
Barley fodder, - - - -	26	F	73.1	58.9	69.9	64.0	52.5	68.4	62.7
Average, - - - - -	—	—	**71.7**	**59.9**	**71.2**	**60.7**	**54.4**	**67.5**	**62.4**
Barley and pea fodder, - -	7	C	81.1	64.8	67.0	49.3	58.4	65.1	60.2
Barley and pea fodder, - -	7	D	73.2	54.5	55.8	37.6	33.9	55.2	49.4
Average, - - - - -	—	—	**77.2**	**59.7**	**61.4**	**43.5**	**46.2**	**60.2**	**54.8**
Oat and pea fodder, - -	14	A	81.7	74.3	65.7	61.2	38.5	68.7	63.9
Oat and pea fodder, - -	14	B	81.3	72.8	67.1	53.7	23.9	67.1	62.4
Oat and pea fodder, - -	35	D	73.2	70.3	66.9	49.1	41.9	62.9	59.9
Oat and pea fodder, - -	36	A	82.7	74.3	66.8	67.4	63.3	70.2	66.1
Oat and pea fodder, - -	36	B	76.5	65.1	56.2	60.2	54.4	61.7	57.3
Average, - - - - -	—	—	**79.1**	**71.4**	**64.5**	**58.3**	**44.4**	**66.1**	**61.9**
Oat fodder, - - - - -	15	C	75.7	68.4	63.5	62.6	43.8	65.4	61.9
Oat fodder, - - - - -	15	E	74.9	71.3	62.7	57.8	45.7	63.5	60.3
Oat fodder, - - - - -	34	A	67.8	67.5	61.1	43.5	49.1	56.5	53.2
Oat fodder, - - - - -	37	C	71.8	68.1	60.0	55.6	65.0	60.2	56.7
Oat fodder, - - - - -	37	D	72.8	72.3	66.9	53.6	67.9	63.3	59.6
Average, - - - - -	—	—	**72.6**	**69.5**	**62.3**	**54.6**	**54.3**	**61.8**	**58.3**
Barnyard millet fodder, - -	38	F	57.3	59.8	64.4	58.8	58.1	61.8	57.8
Barnyard millet fodder, - -	41	C	45.0	71.6	68.4	62.5	51.7	65.2	62.0
Barnyard millet fodder, - -	41	D	49.3	71.8	68.3	63.2	53.7	65.6	62.8
Average, - - - - -	—	—	**47.2**	**71.7**	**68.4**	**62.8**	**52.7**	**65.4**	**62.4**
Hungarian fodder, - - - -	16	A	66.7	85.1	68.4	72.7	53.6	70.6	68.6
Hungarian fodder, - - - -	16	B	71.8	81.9	71.7	76.1	62.9	73.8	71.3
Hungarian fodder, - - - -	19	C	61.0	62.5	69.2	70.3	59.6	68.5	64.6
Hungarian fodder, - - - -	19	D	61.6	59.8	66.3	72.2	57.8	67.6	63.6
Average, - - - - -	—	—	**65.3**	**72.3**	**68.9**	**72.8**	**58.5**	**70.1**	**67.0**
Soy bean fodder, - - - -	17	C	80.5	58.2	70.9	44.7	1.8	64.5	61.2
Soy bean fodder, - - - -	17	E	77.0	50.0	73.0	55.5	13.8	67.5	63.4
Soy bean fodder, - - - -	20	B	70.8	59.3	71.7	38.5	27.6	61.0	56.1
Soy bean fodder, - - - -	20	F	67.7	49.3	75.3	43.3	13.0	63.5	58.1
Soy bean fodder, - - - -	39	C	77.8	54.3	73.0	45.5	27.9	63.2	57.0
Soy bean fodder, - - - -	39	D	76.5	45.8	68.7	49.1	21.6	61.9	55.4
Soy bean fodder, - - - -	40	B	74.4	61.5	77.4	49.2	29.0	67.5	62.8
Soy bean fodder, - - - -	40	F	75.9	53.8	75.4	50.4	16.4	66.7	60.8
Average, - - - - -	—	—	**75.1**	**54.0**	**73.2**	**47.0**	**18.9**	**64.5**	**59.4**

TABLE 72.—*(Concluded.)*

FEEDING STUFFS.	Expt. No.	Sheep.	Protein. N. × 6.25.	Fat.	Nit.-free Extract.	Fiber.	Ash.	Organic Matter.	Fuel Value.
Green Fodders and Grasses.			%	%	%	%	%	%	%
Clover rowen, - - - -	18	B	61.4	60.0	63.9	51.5	42.7	59.7	55.6
Clover rowen, - - - -	18	F	62.3	61.5	66.7	53.6	44.1	61.9	57.3
Average, - - - -	—	—	**61.9**	**60.8**	**65.3**	**52.5**	**43.4**	**60.8**	**56.5**
Rowen, mixed grasses and clover, - - - -	44	B	64.9	56.3	71.9	61.8	44.2	67.0	61.3
Rowen, mixed grasses and clover, - - - -	44	F	69.9	54.0	71.3	63.3	48.1	67.8	62.3
Average, - - - -	—	—	**67.4**	**55.2**	**71.6**	**62.6**	**46.6**	**67.4**	**61.8**
Rowen, mostly timothy, - -	25	B	71.9	54.8	67.3	60.0	43.9	65.3	58.8
Rowen, mostly timothy, - -	25	F	71.5	50.9	68.2	67.6	46.5	67.5	61.7
Average, - - - -	—	—	**71.7**	**52.0**	**67.8**	**63.8**	**45.2**	**66.4**	**60.3**
Sweet corn fodder, - - -	21	C	58.6	79.2	73.3	53.6	46.4	67.5	64.5
Sweet corn fodder, - - -	21	D	52.5	77.3	74.9	54.9	54.9	68.4	65.4
Sweet corn fodder, - - -	22	B	66.8	82.1	77.4	59.8	53.2	73.2	69.3
Sweet corn fodder, - - -	22	F	66.1	81.3	79.1	61.6	47.4	74.5	70.5
Sweet corn fodder, - - -	24	C	68.7	79.8	82.4	72.2	51.3	78.8	75.1
Sweet corn fodder, - - -	24	D	57.9	76.2	75.9	57.9	49.4	70.4	66.2
Sweet corn fodder, - - -	42	B	60.3	70.6	73.6	58.3	51.7	68.6	64.5
Sweet corn fodder, - - -	42	F	61.1	72.1	73.4	60.5	54.3	69.1	65.1
Sweet corn fodder, - - -	45	C	63.2	69.6	73.5	67.1	55.5	70.6	67.1
Sweet corn fodder, - - -	45	D	57.9	71.0	73.8	58.6	61.0	68.2	64.6
Average, - - - -	—	—	**61.3**	**75.9**	**75.7**	**60.5**	**52.5**	**70.9**	**67.2**
Cow pea fodder, - - - -	23	C	72.7	62.5	84.2	57.8	28.2	75.9	71.2
Cow pea fodder, - - - -	23	D	75.3	56.3	84.2	57.1	19.5	76.0	70.9
Cow pea fodder, - - - -	43	C	77.3	60.0	76.4	62.4	19.9	72.1	66.1
Cow pea fodder, - - - -	43	D	77.0	58.6	77.5	61.0	23.2	72.1	66.3
Average, - - - -	—	—	**75.6**	**59.4**	**80.6**	**59.6**	**22.7**	**74.0**	**68.6**
Canada pea fodder, - - -	27	C	81.1	50.0	71.3	62.4	37.8	71.0	64.3
Canada pea fodder, - - -	27	D	83.0	54.8	70.8	62.4	46.9	71.7	65.0
Average, - - - -	—	—	**82.0**	**52.4**	**71.0**	**62.4**	**42.3**	**71.3**	**64.7**

DETAILED DESCRIPTION OF DIGESTION EXPERIMENTS WITH SHEEP, 1895–96.

The animals used in the following experiments were all wethers, dropped in the spring of 1893. Sheep A, C, D and F were grade Shropshires, and sheep B was a grade Merino. They were the same sheep that were used in the experiments of 1894–95. Experiments No. 28 and No. 29 were made on samples of clover rowen that came from a lot that was all cut at one time, the conditions being the same in all respects, except that the crop on half the area was hauled to the barn at once after cutting, and dried carefully by spreading thinly on a scaffold,

while the other portion was field cured in the usual way. The field-cured portion was dried by being spread thinly for three or four hours the day of cutting. It was then put into small heaps and left uncovered for two days, when it was spread and dried again for five or six hours, then put into heaps and covered, and left for six days, when it was aired and hauled. The hay seemed well cured. A slight sprinkle of rain fell while the hay was in heaps and covered.

DIGESTION EXPERIMENT NO. 28.

Clover rowen, field cured. A little past full bloom. The experiment began December 5, 1895, and continued twelve days. The feces were collected for the five days from December 12, at 6:45 A. M., to December 17, at 6:45 A. M. Each animal, sheep A and B, was fed daily 800 grams of the rowen. The experiment was normal throughout, the sheep eating vigorously.

DIGESTION EXPERIMENT NO. 29.

Clover rowen, barn cured. A little past full bloom. The experiment began December 5, 1895, and continued twelve days. The feces were collected for the five days from December 12, at 6:45 A. M., to December 17, at 6:45 A. M. Each animal, sheep C and D, was fed daily 800 grams of the rowen. The experiment was normal throughout, the sheep eating vigorously.

DIGESTION EXPERIMENT NO. 30.

Fine rowen of mixed grasses. The experiment began January 9, 1896, and continued twelve days. The feces were collected for the five days from January 16, at 6:45 A. M., to January 21, at 6:45 A. M. Each animal, sheep A, B, C and D, was fed daily 800 grams of the rowen, and all four went through the experiment nicely, eating full rations.

DIGESTION EXPERIMENT NO. 31.

Oat hay. This was a fair grade hay, nearly free from weeds and sharlock. The seeds were about two-thirds grown and did not shell. The experiment began January 31, 1896, and continued twelve days. The feces were collected for the five days from February 7, at 7 A. M., to February 12, at 7 A. M. Each animal, sheep A, B, C and D, was fed daily 800 grams of the hay. Sheep A, B and C left some uneaten butts, which were sampled, beginning with February 4. Sheep D also began later to leave uneaten butts, which were sampled from February 8.

DIGESTION EXPERIMENT NO. 32.

Coarse bran with fine rowen. The rowen was the same as was used in experiment No. 30. The experiment began February 19, 1896, and continued twelve days. The feces were collected for the five days from February 26, at 6:30 A. M., to March 2, at 6:30 A. M. Each animal, sheep A, B, C and D, was fed daily 400 grams of bran and 400 grams of rowen. The sheep had been fed for some days previous to commencing the experiment on bran and rowen in

different proportions to find the amounts best eaten. The experiment was normal throughout. Sheep A and B had no salt in their mangers the last eight days of the test. Sheep C and D had salt every day.

DIGESTION EXPERIMENT NO. 33.

No. 2 wheat middlings with fine rowen. The rowen was the same in this experiment as in No. 30 and No. 32. The experiment began March 25, 1896, and continued twelve days. The feces were collected for the five days from March 20, at 6:30 A. M., to March 25, at 6:30 A. M. Each animal, sheep A, B, C and D, was fed daily 400 grams of middlings and 400 grams of rowen. Everything was normal throughout the period.

DIGESTION EXPERIMENT NO. 34.

Oat fodder, fed green. This and the following experiments with green fodders were made particularly to test the digestibility of fodders used in feeding tests with milch cows. The general plan was to feed three days without sampling, then four days taking sample 1, then four days taking sample 2, then one day without sampling. This had at times to be modified to meet various conditions, particularly the weather. This experiment began July 7, 1896, and continued twelve days. The feces were collected for the five days from July 14, at 8:30 A. M., to July 19, at 8:30 A. M. Each animal, sheep A and B, was fed daily 2,740 grams of the fodder. The first sample was taken July 10. The oats were full size, seeds about half grown, stems large and slightly woody. The second sample was taken July 15. The oats were full grown and beginning to seed, some of the stems turning yellow and quite woody. Neither sheep ate full rations, and B left so much uneaten that he was dropped from the experiment. The experiment was repeated later with sheep C and D as No. 37. In this latter test less fodder was fed per day.

DIGESTION EXPERIMENT NO. 35.

Oat and pea fodder, fed green. The experiment began July 7, 1896, and continued twelve days. The feces were collected for the five days from July 14, at 8:30 A. M., to July 19, at 8:30 A. M. Each animal, sheep C and D, was fed daily 2,740 grams of the fodder. Two samples were taken, but one was lost. In the second sample, taken July 15, the oat stems were turning yellow and quite woody. The seed was about half grown. The peas were quite badly lodged and many stems blackened. There were few blossoms and many pods, some with seeds full grown. Neither sheep ate the full ration, and on account of the large amount of uneaten residue C was dropped from the experiment. This test was repeated later with sheep A and B as experiment No. 36, in which less fodder was fed per day.

DIGESTION EXPERIMENT NO. 36.

Oat and pea fodder, fed green. The experiment began July 20, 1896, and continued twelve days. The feces were collected for the five days from July 27, at 7 A. M., to August 1, at 7 A. M. Each animal, sheep A and B, was fed daily 2,340 grams of the fodder. At the time the first sample was taken, July 23, the oats were in the early milk stage. The peas were fairly succulent. Stems lodged and lower parts turned brown. Many pods and seeds developed. The second sample was lost. Both sheep ate full rations.

DIGESTION EXPERIMENT NO. 37.

Oat fodder, fed green. The experiment began July 20, 1896, and continued twelve days. The feces were collected for the five days from July 27, at 7 A. M., to August 1, at 7 A. M. Each animal, sheep C and D, was fed daily 2,340 grams of the fodder. At the time the first sample was taken, July 23, the oats were quite succulent, in early seed stage (watery). The second sample was taken July 27. The oats were in the early milk stage, quite green and succulent. Both sheep went through the test nicely, eating full rations.

DIGESTION EXPERIMENT NO. 38.

Millet fodder, fed green. The experiment began August 5, 1896, and continued twelve days. The feces were collected for the five days from August 12, at 6:30 A. M., to August 17, at 6:30 A. M. Each animal, sheep B and F, was fed daily 2,340 grams of the fodder. The first sample was taken August 8, the millet being in bloom, most of the heads grown, and quite succulent. The second sample, taken August 12, was from bloom to early seed stage, with stems slightly woody. Sheep F ate all his fodder, but B left some uneaten residue, which was sampled for the eight days from August 9 to 17.

DIGESTION EXPERIMENT NO. 39.

Soy bean fodder, fed green. The experiment began August 5, 1896, and continued twelve days. The feces were collected for the five days from August 12, at 6:30 A. M., to August 17, at 6:30 A. M. The first sample was taken August 8, when the beans were in early bloom and growing rapidly. At the time the second sample was taken, August 12, the beans were generally in bloom, but not full grown. Each animal, sheep C and D, was fed daily 2,340 grams of the fodder, and both ate full rations throughout the experiment.

DIGESTION EXPERIMENT NO. 40.

Soy bean fodder, fed green. The experiment began August 17, 1896, and continued fourteen days. The feces were collected for the seven days from August 24, at 6:30 A. M., to August 31, at 6:30 A. M. The fodder was from a second sowing. At the time of taking of the first sample, August 20, it was about two-thirds grown, in full bloom, with a few pods forming. The second sample, taken August 24, was mostly in bloom, and beginning to seed and quite succulent. The third sample was taken August 28. The beans were from bloom to early seed stage. Each animal, sheep B and F, was fed daily 2,340 grams of the fodder. During the first few days of the experiment sheep B left some of the leaves uneaten, but afterward ate full ration. For this reason the experiment was continued two days longer than usual, and the feces were collected for seven days. In the tables the experiment is calculated for five days to correspond with the others.

DIGESTION EXPERIMENT NO. 41.

Millet fodder, fed green. The experiment began August 19, 1896, and continued fourteen days. The feces were collected for the seven days from August 24, at 6:30 A. M., to August 31, at 6:30 A. M. The sample taken August 20

was in bloom to early seed stage, with rather woody stems. The second sample, taken August 24, was lost. A third sample was taken August 28. The millet was mostly in the early seed stage. Each animal, sheep C and D, was fed daily 2,340 grams of the fodder. Sheep C left some uneaten butts during the first part of the experiment, after which full rations were eaten. As in experiment No. 40, it was thought best to continue the experiment two days longer than usual, and the feces were collected for seven days. For the sake of comparison the results are calculated for five days.

DIGESTION EXPERIMENT NO. 42.

Sweet corn fodder, fed green. The experiment began August 31, 1896, and continued twelve days. The feces were collected for the five days from September 7, at 6:30 A. M., to September 12, at 6:30 A. M. The first sample was taken September 3. The corn was of the "Branching Sweet" variety. Many of the ears were in the roasting stage, some greener. The stalks were of good size and the proportion of ears large. The second sample was taken September 7. The ears were in the roasting stage and stalks quite succulent. Each animal, sheep B and F, was fed daily 2,740 grams of the fodder. For the first day or two only 2,340 grams were fed, but as the sheep seemed hungry the ration was increased. Both sheep went through the experiment nicely.

DIGESTION EXPERIMENT NO. 43.

Cow pea fodder, fed green. The experiment began August 31, 1896, and continued twelve days. The feces were collected for the five days from September 7, at 6:30 A. M., to September 12, at 6:30 A. M. Two samples were taken, one September 3, the other September 7. In the first the vines were about three-fourths grown, beginning to twine, and quite succulent. In the second the vines had attained a medium heavy growth, though not quite full grown, and were twining somewhat. Each animal, sheep C and D, was fed daily 2,340 grams of the fodder. The experiment seemed to be normal throughout.

DIGESTION EXPERIMENT NO. 44.

Rowen, mixed grasses and clover, fed green. The experiment began September 14, 1896, and continued twelve days. The feces were collected for the five days from September 21, at 6:30 A. M., to September 26, at 6:30 A. M. Two samples were taken, one September 17, the other September 21. In both the proportion of clover was about one-fifth; the grasses were fine. Each animal, sheep B and F, was fed 2,340 grams daily of the rowen.

DIGESTION EXPERIMENT NO. 45.

Sweet corn fodder, fed green. The experiment began September 14, 1896, and continued twelve days. The feces were collected for the five days from September 21, at 6:30 A. M., to September 26, at 6:30 A. M. Two samples were taken, the first September 17, the second September 21. The corn was of the "Branching Sweet" variety, as in experiment No. 42. In both samples the stalks were green and succulent, and the ears in the early roasting stage. Each animal, sheep C and D, was fed daily 2,740 grams of the fodder. The details of this experiment are omitted for lack of space, but the results are summarized in table 72, page 251.

DIGESTION EXPERIMENT No. 28.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1622	Field-cured clover rowen, - -	15.1	15.7	3.6	37.4	21.0	7.2	77.7	3.841
	Feces.								
1609	Sheep A, - -	8.0	15.6	3.8	34.6	27.6	10.4	81.6	4.316
1610	Sheep B, - -	8.5	14.5	3.8	35.5	27.4	10.3	81.2	4.384

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	4000	628	144	1496	840	288	3108
Sheep B, - - -	4000	628	144	1496	840	288	3108
Feces for Five Days.							
Sheep A, - - -	1595	249	60	552	440	166	1301
Sheep B, - - -	1512	219	57	537	414	156	1227
Amounts Digested.							
Sheep A, - - -	—	379	84	944	400	122	1807
Sheep B, - - -	—	409	87	959	426	132	1881
Percentage Digested.		%	%	%	%	%	%
Sheep A, - - -	—	60.3	58.3	63.1	47.6	42.4	58.1
Sheep B, - - -	—	65.1	60.4	64.1	50.7	45.8	60.5
Average, - -	—	62.7	59.4	63.6	49.1	44.1	59.3

Fuel value of food for five days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	15364	6884	8480	330	8150	53.0
Sheep B, - -	15364	6628	8736	356	8380	54.5
Average, - -	—	—	—	—	—	53.8

DIGESTION EXPERIMENT No. 29.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1623	Barn-cured clover rowen, - -	14.6	17.4	3.8	37.2	19.7	7.3	78.1	3.903
	Feces.								
1611	Sheep C, - -	8.6	14.0	3.9	36.6	27.5	9.4	82.0	4.386
1612	Sheep D, - -	8.1	15.3	3.8	35.5	27.2	10.1	81.8	4.328

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams	Grams.	Grams.	Grams.	Grams.
Sheep C, - - -	4000	696	152	1488	788	292	3124
Sheep D, - - -	4000	696	152	1488	788	292	3124
Feces for Five Days.							
Sheep C, - - -	1537	215	60	563	422	145	1260
Sheep D, - - -	1605	246	61	570	436	162	1313
Amounts Digested.							
Sheep C, - - -	—	481	92	925	366	147	1864
Sheep D, - - -	—	450	91	918	352	130	1811
Percentage Digested.		%	%	%	%	%	%
Sheep C, - - -	—	69.1	60.5	62.2	46.4	50.3	59.7
Sheep D, - - -	—	64.7	59.9	61.7	44.7	44.5	58.0
Average, - -	—	66.9	60.2	61.9	45.6	47.4	58.9

Fuel value of food for five days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep C, - -	15612	6741	8871	418	8453	54.1
Sheep D, - -	15612	6946	8666	392	8274	53.0
Average, - -	—	—	—	—	—	53.6

DIGESTION EXPERIMENT No. 30.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1624	Rowen, - -	10.5	14.4	4.4	42.9	21.1	6.7	82.8	4.093
	Feces.								
1626	Sheep A, - -	6.6	13.4	6.7	41.4	20.8	11.1	82.3	4.561
1627	Sheep B, - -	5.6	13.4	6.5	41.6	20.6	12.3	82.1	4.477
1628	Sheep C, - -	5.3	13.1	6.8	42.3	20.3	12.2	82.5	4.537
1629	Sheep D, - -	4.8	13.0	6.8	41.6	21.8	12.0	83.2	4.527

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	4000	576	176	1716	844	268	3312
Sheep B, - - -	4000	576	176	1716	844	268	3312
Sheep C, - - -	4000	576	176	1716	844	268	3312
Sheep D, - - -	4000	576	176	1716	844	268	3312
Feces for Five Days.							
Sheep A, - - -	1385	186	93	573	288	154	1140
Sheep B, - - -	1366	183	89	568	281	168	1121
Sheep C, - - -	1280	168	87	541	260	156	1056
Sheep D, - - -	1370	178	93	570	299	164	1140
Amounts Digested.							
Sheep A, - - -	—	390	83	1143	556	114	2172
Sheep B, - - -	—	393	87	1148	563	100	2191
Sheep C, - - -	—	408	89	1175	584	112	2256
Sheep D, - - -	—	398	83	1146	545	104	2172
Percentage Digested.		%	%	%	%	%	%
Sheep A, - - -	—	67.7	47.2	66.6	65.9	42.5	65.6
Sheep B, - - -	—	68.2	49.4	66.9	66.7	37.3	66.2
Sheep C, - - -	—	70.8	50.6	68.5	69.2	41.8	68.1
Sheep D, - - -	—	69.1	47.2	66.8	64.6	38.8	65.6
Average, - -	—	69.0	48.6	67.2	66.6	40.1	66.4

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	16372	6316	10056	339	9717	59.3
Sheep B, - -	16372	6114	10258	342	9916	60.6
Sheep C, - -	16372	5806	10566	355	10211	62.4
Sheep D, - -	16372	6201	10171	347	9824	60.0
Average, - -	—	—	—	—	—	60.6

DIGESTION EXPERIMENT No. 31.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1625	Oat hay, - -	12.3	9.8	4.1	42.5	25.8	5.5	82.2	4.033
	Feces.								
1630	Sheep A, - -	5.1	10.4	3.6	44.1	29.6	7.2	87.7	4.568
1631	Sheep B, - -	5.4	9.7	3.3	43.7	31.2	6.7	87.9	4.534
1632	Sheep C, - -	4.7	9.6	3.5	44.5	30.5	7.2	88.1	4.556
1633	Sheep D, - -	5.1	9.6	3.2	43.2	31.9	7.0	87.9	4.537
	Uneaten Residue.								
1640	Sheep A and D, -	18.9	2.3	.9	26.9	27.4	23.6	57.5	2.716
1638	Sheep B, - -	7.8	4.4	2.7	40.9	38.2	6.0	86.2	4.143
1639	Sheep C, - -	10.7	2.8	1.2	38.6	40.1	6.6	82.7	3.942

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, B, C, D, fed each	4000	392	164	1700	1032	220	3288
Uneaten residue, A, -	261	6	2	70	72	62	150
Uneaten residue, B, -	97	4	3	40	37	6	84
Uneaten residue, C, -	130	4	2	50	52	9	108
Uneaten residue, D, -	57	1	1	15	16	13	33
Actually eaten, A, -	3739	386	162	1630	960	158	3138
Actually eaten, B, -	3903	388	161	1660	995	214	3204
Actually eaten, C, -	3870	388	162	1650	980	211	3180
Actually eaten, D, -	3943	391	163	1685	1016	207	3255
Feces for Five Days.							
Sheep A, - - -	1765	184	64	778	522	127	1548
Sheep B, - - -	1850	179	61	809	577	124	1626
Sheep C, - - -	1709	164	60	761	521	123	1506
Sheep D, - - -	1930	185	62	834	616	135	1697
Amounts Digested.							
Sheep A, - - -	—	202	98	852	438	31	1590
Sheep B, - - -	—	209	100	851	418	90	1578
Sheep C, - - -	—	224	102	889	459	88	1674
Sheep D, - - -	—	206	101	851	400	72	1558
Percentage Digested.		%	%	%	%	%	%
Sheep A, - - -	—	52.3	60.5	52.3	45.6	19.6	50.7
Sheep B, - - -	—	53.9	62.1	51.3	42.0	42.1	49.2
Sheep C, - - -	—	57.7	63.0	53.9	46.8	41.7	52.6
Sheep D, - - -	—	52.7	62.0	50.5	39.4	34.8	47.9
Average, - -	—	**53.3**	**61.3**	**51.6**	**43.5**	**34.6**	**50.1**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	15423	8063	7360	176	7184	46.6
Sheep B, - -	15730	8388	7342	182	7160	45.5
Sheep C - -	15620	7786	7834	195	7639	48.9
Sheep D, - -	15977	8756	7221	179	7042	44.1
Average, - -	—	—	—	—	—	**46.3**

DIGESTION EXPERIMENT No. 32.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1641	Rowen,* - -	13.2	13.5	4.9	40.2	20.7	7.5	79.3	3.985
1643	Coarse bran, -	7.0	15.3	5.4	55.1	11.1	6.1	86.9	4.166
	Feces.								
1634	Sheep A, - -	5.7	11.1	5.1	43.1	22.9	12.1	82.2	4.326
1635	Sheep B, - -	5.9	11.8	6.1	41.8	21.9	12.5	81.6	4.376
1636	Sheep C, - -	5.6	12.1	5.2	43.2	20.5	13.4	81.0	4.267
1637	Sheep D, - -	7.4	12.1	5.2	40.2	21.8	13.3	79.3	4.234

* Same as in No. 30. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	4000	576	206	1906	636	272	3324
Sheep B, - - -	4000	576	206	1906	636	272	3324
Sheep C, - - -	4000	576	206	1906	636	272	3324
Sheep D, - - -	4000	576	206	1906	636	272	3324
Feces for Five Days.							
Sheep A, - - -	1538	171	78	663	352	186	1264
Sheep B, - - -	1518	179	93	634	332	190	1238
Sheep C, - - -	1352	164	70	584	277	181	1095
Sheep D, - - -	1547	187	81	622	337	206	1227
Amounts Digested.							
Sheep A, - - -	—	405	128	1243	284	86	2060
Sheep B, - - -	—	397	113	1272	304	82	2086
Sheep C, - - -	—	412	136	1322	359	91	2229
Sheep D, - - -	—	389	125	1284	299	66	2097
Percentage Digested.		%	%	%	%	%	%
Sheep A, - - -	—	70.3	62.1	65.2	44.7	31.6	62.0
Sheep B, - - -	—	68.9	54.9	66.7	47.8	30.2	62.7
Sheep C, - - -	—	71.5	66.0	69.4	56.4	33.5	67.1
Sheep D, - - -	—	67.5	60.7	67.4	47.0	24.3	63.1
Average, - -	—	**69.6**	**60.9**	**67.2**	**49.0**	**29.9**	**63.7**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	16302	6653	9649	352	9297	57.0
Sheep B, - -	16302	6643	9659	347	9312	57.1
Sheep C, - -	16302	5769	10533	358	10175	62.4
Sheep D, - -	16302	6550	9752	339	9413	57.8
Average, - -	—	—	—	—	—	**58.6**

DIGESTION EXPERIMENT No. 33.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1642	Rowen,* - -	8.8	13.1	4.8	44.3	22.0	7.0	84.2	4.131
1644	No. 2 wheat middlings, - -	8.4	18.7	5.8	52.5	9.6	5.0	86.6	4.210
	Feces.								
1645	Sheep A, - -	10.1	12.3	4.4	41.5	21.3	10.4	79.5	4.153
1646	Sheep B, - -	8.3	11.5	5.0	41.2	21.7	12.3	79.4	4.187
1647	Sheep C, - -	11.2	13.3	4.3	37.5	20.7	13.0	75.8	4.062
1648	Sheep D, - -	9.7	13.7	4.6	40.9	19.2	11.9	78.4	4.128

* Same as in Nos. 30 and 32. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	4000	636	212	1936	632	240	3416
Sheep B, - - -	4000	636	212	1936	632	240	3416
Sheep C, - - -	4000	636	212	1936	632	240	3416
Sheep D, - - -	4000	636	212	1936	632	240	3416
Feces for Five Days.							
Sheep A, - - -	1352	166	60	561	288	140	1075
Sheep B, - - -	1322	152	66	545	287	162	1050
Sheep C, - - -	1394	185	60	523	289	181	1057
Sheep D, - - -	1366	187	63	559	262	162	1071
Amounts Digested.							
Sheep A, - - -	—	470	152	1375	344	100	2341
Sheep B, - - -	—	484	146	1391	345	78	2366
Sheep C, - - -	—	451	152	1413	343	59	2359
Sheep D, - - -	—	449	149	1377	370	78	2345
Percentages Digested.		%	%	%	%	%	%
Sheep A, - - -	—	73.9	71.7	71.0	54.4	41.7	68.5
Sheep B, - - -	—	76.1	68.9	71.9	54.6	32.5	69.2
Sheep C, - - -	—	70.9	71.7	73.0	54.3	24.6	69.1
Sheep D, - - -	—	70.6	70.3	71.1	58.6	32.5	68.7
Average, - -	—	72.9	70.7	71.7	55.5	32.8	68.9

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	16682	5615	11067	409	10658	63.9
Sheep B, - -	16682	5535	11147	411	10736	64.4
Sheep C, - -	16682	5662	11020	390	10630	63.7
Sheep D, - -	16682	5639	11043	388	10655	63.9
Average, - -	—	—	—	—	—	64.0

DIGESTION EXPERIMENT No. 34.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Oat fodder:*								
1669	Sample 1, -	67.1	3.5	1.5	15.7	9.7	2.5	30.4	1.493
1670	Sample 2, -	67.0	3.0	1.5	16.3	9.9	2.3	30.7	1.474
	Average, -	67.0	3.3	1.5	16.0	9.8	2.4	30.6	1.484
	Feces.								
1678	Sheep A, - -	6.3	6.9	3.2	40.2	35.5	7.9	85.8	4.355
	Uneaten Residue.								
1789	Sheep A, - -	5.9	3.6	.9	36.0	46.6	7.0	87.1	4.092

* Fed green.

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, fed, - -	13700	452	206	2192	1343	329	4193
Uneaten residue, A, -	45	2	—	16	21	3	39
Actually eaten, A, -	13655	450	206	2176	1322	326	4154
Feces for Five Days.							
Sheep A, - - -	2104	145	67	846	747	166	1805
Amounts Digested.							
Sheep A, - - -	—	305	139	1330	575	160	2349
Percentage Digested.		%	%	%	%	%	%
Sheep A, - - -	—	67.8	67.5	61.1	43.5	49.1	56.5

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	20147	9163	10984	265	10719	53.2

DIGESTION EXPERIMENT No. 35.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1671	Oat & pea fodder,*	68.8	4.0	1.6	15.1	8.3	2.2	29.0	1.436
	Feces.								
1679	Sheep D, - -	6.6	8.3	3.7	38.7	32.8	9.9	83.5	4.268

* Fed green. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep D, - - -	13700	548	219	2069	1137	301	3973
Feces for Five Days.							
Sheep D, - - -	1767	147	65	684	579	175	1475
Amounts Digested.							
Sheep D, - - -	—	401	154	1385	558	126	2498
Percentage Digested.		%	%	%	%	%	%
Sheep D, - - -	—	73.2	70.3	66.9	49.1	41.9	62.9

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep D, - -	19673	7541	12132	349	11783	59.9

DIGESTION EXPERIMENT No. 36.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
1672	Oat & pea fodder,*	71.4	4.7	1.3	10.6	10.0	2.0	26.6	1.312
1790	Uneaten residue, B,	6.4	19.9	2.0	38.3	27.4	6.0	87.6	4.190
	Feces.								
1680	Sheep A, - -	8.0	8.6	3.5	37.4	34.7	7.8	84.2	4.361
1681	Sheep B, - -	7.6	9.1	3.8	38.5	33.4	7.6	84.8	4.412

* Fed green. † Per gram as determined in the calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	11700	550	152	1240	1170	234	3112
Sheep B, - - -	11700	550	152	1240	1170	234	3112
Uneaten residue, B, -	135	27	3	52	37	8	119
Actually eaten, A, -	11700	550	152	1240	1170	234	3112
Actually eaten, B, -	11565	523	149	1188	1133	226	2993
Feces for Five Days.							
Sheep A, - - -	1102	95	39	412	382	86	928
Sheep B, - - -	1351	123	52	520	451	103	1146
Amounts Digested.							
Sheep A, - - -	—	455	113	828	788	148	2184
Sheep B, - - -	—	400	97	668	682	123	1847
Percentage Digested.		%	%	%	%	%	%
Sheep A, - - -	—	82.7	74.3	66.8	67.4	63.3	70.2
Sheep B, - - -	—	76.5	65.1	56.2	60.2	54.4	61.7
Average, - -	—	**79.6**	**69.7**	**61.5**	**63.8**	**58.9**	**66.0**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep A, - -	15350	4806	10544	396	10148	66.1
Sheep B, - -	14784	5961	8823	348	8475	57.3
Average, - -	—	—	—	—	—	**61.7**

DIGESTION EXPERIMENT No. 37.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Oat fodder:*								
1673	Sample 1, -	74.0	2.6	1.1	11.7	8.4	2.2	23.8	1.162
1674	Sample 2, -	73.0	2.8	1.2	12.7	8.2	2.1	24.9	1.215
	Average, -	**73.5**	**2.7**	**1.2**	**12.2**	**8.3**	**2.1**	**24.4**	**1.189**
	Feces.								
1682	Sheep C, - -	6.5	6.8	3.4	43.7	33.0	6.6	86.9	4.459
1683	Sheep D, - -	7.1	7.1	3.2	38.9	37.1	6.6	86.3	4.451

* Fed green. † Per gram as determined in the calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C, - - -	11700	316	141	1427	971	246	2855
Sheep D, - - -	11700	316	141	1427	971	246	2855
Feces for Five Days.							
Sheep C, - - -	1307	89	45	571	431	86	1136
Sheep D, - - -	1216	86	39	473	451	80	1049
Amounts Digested.							
Sheep C, - - -	—	227	96	856	540	160	1719
Sheep D, - - -	—	230	102	954	520	166	1806
Percentages Digested.		%	%	%	%	%	%
Sheep C, - - -	—	71.8	68.1	60.0	55.6	65.0	60.2
Sheep D, - - -	—	72.8	72.3	66.9	53.6	67.9	63.3
Average, - -	—	**72.3**	**70.2**	**63.5**	**54.6**	**66.4**	**61.8**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep C, - -	13910	5828	8082	197	7885	56.7
Sheep D, - -	13910	5412	8498	200	8298	59.6
Average, - -	—	—	—	—	—	**58.2**

DIGESTION EXPERIMENT No. 38.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Millet fodder:								
1696	Sample 1, -	75.6	1.7	.6	12.2	7.8	2.1	22.3	1.036
1675	Sample 2, -	75.5	2.0	.9	12.1	7.3	2.2	22.3	1.044
	Average, -	**75.6**	**1.8**	**.7**	**12.2**	**7.6**	**2.1**	**22.3**	**1.040**
	Feces.								
1685	Sheep F, - -	6.2	7.7	2.8	43.3	31.2	8.7	85.0	4.293

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep F, - - -	11700	211	82	1427	889	246	2609
Feces.							
Sheep F, - - -	1173	90	33	508	366	103	997
Amounts Digested.							
Sheep F, - - -	—	121	49	919	523	143	1612
Percentages Digested.		%	%	%	%	%	%
Sheep F, - - -	—	57.3	59.8	64.4	58.8	58.1	61.8

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep F, - -	12168	5035	7133	105	7028	57.8

DIGESTION EXPERIMENT No. 39.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Soy bean fodder:*								
1697	Sample 1, -	79.5	3.1	.7	8.0	6.4	2.3	18.2	.799
1698	Sample 2, -	77.1	3.3	.9	8.7	7.6	2.4	20.5	1.010
	Average, -	**78.3**	**3.2**	**.8**	**8.4**	**7.0**	**2.3**	**19.4**	**.905**
	Feces.								
1686	Sheep C, - -	5.0	7.6	4.0	24.4	41.1	17.9	77.1	3.967
1687	Sheep D, - -	4.8	7.8	4.5	27.3	36.9	18.7	76.5	3.962

* Fed green. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C, - - -	11700	374	94	983	819	269	2270
Sheep D, - - -	11700	374	94	983	819	269	2270
Feces for Five Days.							
Sheep C, - - -	1085	83	43	265	446	194	837
Sheep D, - - -	1129	88	51	308	417	211	864
Amounts Digested.							
Sheep C, - - -	10615	291	51	718	373	75	1433
Sheep D, - - -	10571	286	43	675	402	58	1406
Percentage Digested.		%	%	%	%	%	%
Sheep C, - - -	—	77.8	54.3	73.0	45.5	27.9	63.2
Sheep D, - - -	—	76.5	45.8	68.7	49.1	21.6	61.9
Average, - -	—	**77.2**	**50.1**	**70.9**	**47.3**	**24.8**	**62.6**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep C, - -	10588	4304	6284	253	6031	57.0
Sheep D, - -	10588	4473	6115	249	5866	55.4
Average, - -	—	—	—	—	—	**56.2**

DIGESTION EXPERIMENT No. 40.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Soy bean fodder:*								
1676	Sample 1, -	76.0	3.8	1.2	10.6	6.0	2.4	21.6	1.053
1699	Sample 2, -	77.4	3.6	.9	8.6	7.2	2.3	20.3	.995
1700	Sample 3, -	75.8	2.7	.9	11.8	6.5	2.3	21.9	1.044
	Average, -	**76.4**	**3.4**	**1.0**	**10.3**	**6.6**	**2.3**	**21.3**	**1.031**
	Feces.								
1688	Sheep B, - -	5.1	9.6	4.3	25.8	37.1	18.1	76.8	4.008
1689	Sheep F, - -	5.0	8.7	4.8	26.7	34.5	20.3	74.7	4.018

* Fed green. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep B, - - -	11700	398	117	1205	772	269	2492
Sheep F, - - -	11700	398	117	1205	772	269	2492
Feces for Five Days.							
Sheep B, - - -	1056	102	45	272	392	191	811
Sheep F, - - -	1110	96	54	296	383	225	829
Amounts Digested.							
Sheep B, - - -	—	296	72	933	380	78	1681
Sheep F, - - -	—	302	63	909	389	44	1663
Percentage Digested.		%	%	%	%	%	%
Sheep B, - - -	—	74.4	61.5	77.4	49.2	29.0	67.5
Sheep F, - - -	—	75.9	53.8	75.4	50.4	16.4	66.7
Average, - -	—	**75.2**	**57.7**	**76.4**	**49.8**	**22.7**	**67.1**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep B, - -	12063	4232	7831	258	7573	62.8
Sheep F, - -	12063	4460	7603	263	7340	60.8
Average, - -	—	—	—	—	—	**61.8**

DIGESTION EXPERIMENT No. 41.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Barnyard millet:								
1677	Sample 1, -	66.5	2.1	1.4	17.7	10.1	2.2	31.3	1.466
1701	Sample 2, -	71.1	1.2	.7	15.8	9.2	2.0	26.9	1.243
	Average, -	**68.8**	**1.7**	**1.0**	**16.8**	**9.6**	**2.1**	**29.1**	**1.355**
1791	Uneaten residue, C,	4.8	2.2	.9	51.2	33.8	7.1	88.1	3.972
	Feces.								
1690	Sheep C, - -	6.9	7.9	2.4	44.3	30.0	8.5	84.6	4.242
1691	Sheep D, - -	6.1	7.4	2.4	45.4	30.4	8.3	85.6	4.247

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C and D, - -	11700	199	117	1965	1123	246	3404
Uneaten residue, C, -	57	1	1	29	19	4	50
Actually eaten:							
Sheep C, - -	11643	198	116	1936	1104	242	3354
Sheep D, - -	11700	199	117	1965	1123	246	3404
Feces for Five Days.							
Sheep C, - - -	1380	109	33	611	414	117	1167
Sheep D, - - -	1370	101	33	622	416	114	1172
Amounts Digested.							
Sheep C, - - -	10263	89	83	1325	690	125	2187
Sheep D, - - -	10330	98	84	1343	707	132	2232
Percentage Digested.		%	%	%	%	%	%
Sheep C, - - -	—	45.0	71.6	68.4	62.5	51.7	65.2
Sheep D, - - -	—	49.3	71.8	68.3	63.2	53.7	65.6
Average, - -	—	**47.2**	**71.7**	**68.4**	**62.8**	**52.7**	**65.4**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep C, - -	15628	5854	9774	77	9697	62.0
Sheep D, - -	15854	5817	10037	85	9952	62.8
Average, - -	—	—	—	—	—	**62.4**

DIGESTION EXPERIMENT No. 42.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Sweet corn fodder:*								
1727	Sample 1, -	79.4	2.0	.5	12.2	4.7	1.2	19.4	.911
1702	Sample 2, -	82.7	1.7	.5	10.4	3.6	1.1	16.2	.750
	Average, -	**81.1**	**1.8**	**.5**	**11.3**	**4.2**	**1.1**	**17.8**	**.831**
	Feces.								
1692	Sheep B, - -	6.6	10.9	2.2	45.5	26.7	8.1	85.3	4.361
1693	Sheep F, - -	6.9	10.9	2.1	46.6	25.7	7.8	85.3	4.351

* Fed green. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams	Grams.	Grams.	Grams.	Grams.
Sheep B, - - -	13700	247	68	1548	575	151	2438
Sheep F, - - -	13700	247	68	1548	575	151	2438
Feces for Five Days.							
Sheep B, - - -	898	98	20	408	240	73	766
Sheep F, - - -	884	96	19	412	227	69	754
Amounts Digested.							
Sheep B, - - -	—	149	48	1140	335	78	1672
Sheep F, - - -	—	151	49	1136	348	82	1684
Percentage Digested.		%	%	%	%	%	%
Sheep B, - - -	—	60.3	70.6	73.6	58.3	51.7	68.6
Sheep F, - - -	—	61.1	72.1	73.4	60.5	54.3	69.1
Average, - -	—	**60.7**	**71.4**	**73.5**	**59.4**	**53.0**	**68.9**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep B, - -	11385	3916	7469	130	7339	64.5
Sheep F, - -	11385	3841	7539	131	7408	65.1
Average, - -	—	—	—	—	—	**64.8**

DIGESTION EXPERIMENT No. 43.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Cow pea fodder:*								
1705	Sample 1, -	84.7	3.0	.6	6.3	3.6	1.8	13.5	.643
1703	Sample 2, -	84.0	2.8	.6	6.9	3.8	1.9	14.1	.663
	Average, -	**84.4**	**2.9**	**.6**	**6.6**	**3.7**	**1.8**	**13.8**	**.653**
	Feces.								
1694	Sheep C, - -	5.6	11.7	4.2	27.8	24.9	25.8	68.6	3.600
1695	Sheep D, - -	4.8	12.1	4.6	27.0	26.3	25.2	70.0	3.653

* Fed green. † Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C, - - -	11700	339	70	772	433	211	1614
Sheep D, - - -	11700	339	70	772	433	211	1614
Feces for Five Days.							
Sheep C, - - -	656	77	28	182	163	169	450
Sheep D, - - -	643	78	29	174	169	162	450
Amounts Digested.							
Sheep C, - - -	—	262	42	590	270	42	1164
Sheep D, - - -	—	261	41	598	264	49	1164
Percentage Digested.		%	%	%	%	%	%
Sheep C, - - -	—	77.3	60.0	76.4	62.4	19.9	72.1
Sheep D, - - -	—	77.0	58.6	77.5	61.0	23.2	72.1
Average, - -	—	**77.2**	**59.3**	**77.0**	**61.7**	**21.6**	**72.1**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep C, - -	7640	2362	5278	228	5050	66.1
Sheep D, - -	7640	2349	5291	227	5064	66.3
Average, - -	—	—	—	—	—	**66.2**

DIGESTION EXPERIMENT No. 44.

Composition of feeding stuffs and feces.

Lab. No.		Water	Protein. N.×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.	Fuel Value.†
	Feeding Stuff.	%	%	%	%	%	%	%	Cal.
	Rowen:								
1704	Sample 1, -	75.7	3.5	1.4	11.3	6.2	1.9	22.4	1.105
1728	Sample 2, -	70.2	4.0	1.6	13.6	8.1	2.5	27.3	1.350
	Average, -	**72.9**	**3.8**	**1.5**	**12.5**	**7.1**	**2.2**	**24.9**	**1.228**
	Feces.								
1732	Sheep B, - -	8.4	12.9	6.4	34.1	26.3	11.9	79.7	4.400
1733	Sheep F, - -	8.1	11.5	6.9	35.9	26.1	11.5	80.4	4.401

† Per gram as determined in calorimeter.

Weights of food eaten, and of feces for five days, and weights and percentages of nutrients digested.

	Total Weight.	Protein. N.×6.25.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Organic Matter.
Eaten in Five Days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep B, - - -	11700	445	176	1462	830	258	2913
Sheep F, - - -	11700	445	176	1462	830	258	2913
Feces for Five Days.							
Sheep B, - - -	1206	156	77	411	317	144	961
Sheep F, - - -	1168	134	81	419	305	134	939
Amounts Digested.							
Sheep B, - - -	—	289	99	1051	513	114	1952
Sheep F, - - -	—	311	95	1043	525	124	1974
Percentage Digested.		%	%	%	%	%	%
Sheep B, - - -	—	64.9	56.3	71.9	61.8	44.2	67.0
Sheep F, - - -	—	69.9	54.0	71.3	63.3	48.1	67.8
Average, - -	—	**67.4**	**55.2**	**71.6**	**62.6**	**46.2**	**67.4**

Fuel value of food for 5 days as determined by the bomb calorimeter.

	Fuel Val. of Food Eaten.	Fuel Val. of Feces.	Fuel Val. of Food Digested.	Fuel Val. of Urea, Etc.	Total Available Fuel Val.	Percent. Available Fuel Val.
	Calories.	Calories.	Calories.	Calories.	Calories.	%
Sheep B, - -	14368	5306	9062	251	8811	61.3
Sheep F, - -	14368	5140	9228	271	8957	62.3
Average, - -	—	—	—	—	—	**61.8**

ANALYSES OF FODDERS AND FEEDING STUFFS.

REPORTED BY W. O. ATWATER AND F. G. BENEDICT.

In connection with the work of the Station during the year, analyses of the following miscellaneous feeding stuffs have been made by the Station chemists. Most of the analyses were made in connection with feeding experiments or experiments upon the growth of plants. In no case were they undertaken merely to increase the amount of data of this class. The method of analysis were those recommended by the Association of Official Agricultural Chemists.

The results of the analyses as calculated to water content at harvest or at the time of analyses are given in table 73, page 280, which follows the description of samples. In this table the materials are grouped somewhat according to their water content at time of taking samples, as follows: Green fodders; silage; cured hay and fodder; grain; and milling products. This order is also observed in the description of samples.

The results calculated to water-free substance (dry matter) as the basis are given in table 74, page 284.

The fuel value of a pound of each of the feeding stuffs as given in the tables was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6, and the number of hundredths of a pound of fat by 42.2, and taking the sum of these three products as the number of calories of potential energy in the materials.

The heats of combustion of the majority of the specimens were also made with the bomb calorimeter. The results of a large number of these determinations have been given in the tabular statements included in the accounts of feeding and digestion experiments with sheep. A compilation of the work of the Station in this field is now being made for publication.

There are two sets of averages given in tables 73 and 74 beyond: the first is the average of the samples analyzed during the past year; the second is the average of all analyses of similar foods made up to the present time in this laboratory.

DESCRIPTION OF SAMPLES.

ANALYSES OF DISTINCT SPECIES OF GRASSES GROWN WITH DIFFERENT QUANTITIES OF FERTILIZERS.

In the year 1892 the Station began a series of experiments on the effect of nitrogenous and of mineral fertilizers on pure species of grasses, which were grown upon small plots (one-eightieth acre each) in the grass garden. The grasses were grown in drills and were kept as free as possible from admixtures of weeds or of other grasses. The experiment was continued for three years. In 1894 it was noticed that many of the plots, especially those having mineral fertilizers only, produced a large proportion of clover, making it difficult to sample the grasses and have the samples pure. Sorrel and other small weeds were also filling up the drills, and it was thought best to remove the grasses and to cultivate and re-seed. This was done in August, 1894. In the spring of 1895 it was noticed that some of the plots were not well stocked. The vacant places were filled out, either by transplanting or by sowing more seed, and the experiment was discontinued for that year, except that the same kinds and quantities of fertilizers were used, but no samples were taken for analysis.

In the spring of 1896 the drills of grasses were found to be well stocked, and the experiment was renewed. The samples of timothy, orchard grass, and meadow fescue described below represent the fifth annual crop grown on plots which had the same kinds and amounts of fertilizers each year, while the brome grass and red-top represent the second annual crop.

GREEN FODDER.

1649, 1654, 1659, 1664 *Timothy (Phleum pratense).*—Grown in the Station grass garden in 1896. The samples were taken July 14, at which time the seed was beginning to form and the stems were fairly succulent. No. 1649 was from a plot without fertilizer. The growth was light, thin, and of a pale color. No. 1654 was from a plot to which was applied dissolved bone-black at the rate of 320 pounds an acre, and muriate of potash at the rate of 160 pounds. Growth very similar to that on 1649. No. 1659 was from a plot which had dissolved bone-black and muriate of potash the same as 1654, and in addition nitrate of soda at the rate of 160 pounds per acre. The growth was heavy and of fair color. No. 1664 was from a plot which had dissolved bone-black and muriate of potash the same as 1654, and in addition nitrate of soda at the rate of 480 pounds per acre. There was a much larger crop than on the other plots, with thick bottom and heavy leaf growth.

1650, 1655, 1660, 1665, *Orchard grass (Dactylis glomerata).*—Grown in the Station grass garden in 1896. The samples were taken June 30, in the early seed stage. The stems were somewhat woody. No. 1650 was from a plot to which no fertilizer was applied. The growth was thin, light, and pale colored. No. 1655 was from a plot to which was applied dissolved bone-black at the rate of 320 pounds, and muriate of potash at the rate of 160 pounds per acre. Growth only slightly heavier than on 1650. No. 1660 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1655, and in addition nitrate of soda at the rate of 160 pounds per acre. The growth was medium heavy, thick, and of fair color. No. 1665 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1655, and in addition nitrate of soda at the rate of 480 pounds per acre. There was a heavy, dense growth, of good color, and a large proportion of leafy, bottom growth.

1651, 1656, 1661, 1666, *Meadow fescue (Festuca elatior).*—Grown in the Station grass garden in 1896. The samples were taken June 30, in the early seed stage. Stems slightly woody. No. 1651 was from a plot which had no fertilizer. The growth was slight, thin and spindled, and of pale color. No. 1656 was from a plot which had dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds. A slightly heavier growth than on 1651, but of pale yellow. No. 1661 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1656, and in addition nitrate of soda at the rate of 160 pounds. Quite a good growth and of fair color. Bottom growth quite heavy. No. 1666 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1656, and in addition nitrate of soda at the rate of 480 pounds per acre. There was a heavy crop of dark green color. Bottom growth very thick.

1652, 1657, 1662, 1667, *Brome grass (Bromus inermis).*—Grown in the Station grass garden in 1896. Samples were taken June 30, in the early seed stage. Stems quite woody. No. 1652 was from a plot to which no fertilizer had been applied. The growth was thin and stemmy. No. 1657 was from a plot which had dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds. A thin growth, somewhat heavier than on 1652. No. 1662 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1657, and in addition nitrate of soda at the rate of 160 pounds per acre. A medium heavy growth of good color; not much leaf growth. No. 1667 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1657, and in addition nitrate of soda at the rate of 480 pounds. Medium heavy growth of dark green color. The growth on the whole was rather stemmy; not equal to timothy, fescue, or orchard grass on corresponding plots.

1653, 1658, 1663, 1668, *Red-top (Agrostis vulgaris).*—Grown in the Station grass garden in 1896. The samples were taken July 14, in the early seed stage. Stems quite succulent, but flower heads rather brown. No. 1653 was from a plot which had no fertilizer. There was a fine thick growth, quite small, not as pale colored as other varieties. No. 1658 was from a plot which had dissolved bone-black at the rate of 320 pounds, and muriate of potash at the rate of 160 pounds, per acre. A little heavier growth than on 1653. No. 1663 was

from a plot which had dissolved bone-black and muriate of potash at the same rate as 1658, and in addition nitrate of soda at the rate of 160 pounds per acre. A thick, fine growth, medium heavy, and of good color. No. 1668 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1658, and in addition nitrate of soda at the rate of 480 pounds per acre. The growth was thick, dark green in color, and quite heavy. There was a slight admixture of timothy on all plots, which was rejected in taking samples.

1675, 1696, *Millet fodder*.—Barnyard millet, sampled August 8 and 12, 1896, in connection with sheep digestion experiment No. 38. The millet was from bloom to early seed stage, the stems being slightly woody.

1677, 1701, *Millet fodder* in about the same stage as Nos. 1675 and 1696. Sampled August 20 and 28, 1896, in connection with sheep feeding experiment No. 41.

1703, 1705, *Cow pea fodder*.—This sample was taken in connection with sheep digestion experiment No. 43. The cow peas were cut September 3 and 7, 1896, at which time they had attained a medium heavy growth, though not full grown. They were beginning to twine, and were quite succulent.

1718–1726, 1731, *Cow pea fodder*.—Grown by the Station in 1896 as part of a special nitrogen experiment. For description of the experiment see pages 101–106 of the Eighth Annual Report, and page 278 of this Report. The samples were taken September 18 and 21. Nos. 1718 and 1719 were from plots without fertilizers. Nos. 1720 and 1721 were from plots to which were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds. Nos. 1722, 1723, and 1731 were grown on plots to which mixed minerals were applied, as in 1720 and 1721, and had in addition 160, 320, and 480 pounds of nitrate of soda per acre respectively. Nos. 1724, 1725, and 1726 were grown on plots to which mixed minerals were applied, as in 1720 and 1721, and had in addition 120, 240, and 360 pounds of sulphate of ammonia per acre respectively.

1669, 1670, *Oat fodder*.—The samples, which were taken July 10 and 15, 1896, were in connection with sheep digestion experiment No. 34. The oats were full grown with large and slightly woody stems. The seeds were about half grown.

1673, 1674, *Oat fodder*.—Sampled July 23 and 27, 1896, in connection with sheep digestion experiment No. 37. The oats were in the early milk stage, quite green and succulent.

1671, 1672, *Oat and pea fodder*.—Used in sheep digestion experiments Nos. 35 and 36 respectively. The samples were taken July 15 and 23, 1896. The oats were full size, stems quite woody, and seeds about half grown. Peas with but few blossoms, and seeds full grown in many pods. The peas were quite badly lodged, and many stems were blackened. The proportion of oats and peas was about half-and-half.

1704, 1728, *Rowen*.—Fine grasses and clover in about the proportion of four to one. Sampled September 17 and 21, 1896, in connection with sheep digestion experiment No. 44.

1702, 1727, 1729, 1730, *Sweet corn fodder.*—"Branching Sweet" variety, in early roasting stage. Stalks quite succulent and proportion of ears large. Nos. 1702 and 1727 were taken September 3 and 7, 1896, in connection with sheep digestion experiment No. 42. Nos. 1729 and 1730 were taken September 17 and 21, 1896, in connection with sheep digestion experiment No. 45.

1697, 1698, *Soy bean fodder.*—Sampled August 8 and 12, 1896, in connection with sheep digestion experiment No. 39. The soy beans were generally in bloom and growing rapidly, but not full grown.

1676, 1699, 1700, *Soy bean fodder.*—Sampled August 20, 24, and 28, 1896, in connection with sheep digestion experiment No. 40. Crop from second sowing, about two-thirds grown, from bloom to early seed stage, and quite succulent.

SILAGE AND CORN STOVER.

1596, *Corn silage.*

1600, *Corn silage.*—Raised from Virginia grown seed, B. and W., white ensilage corn, by L. D. Lyman, of Middlefield. When cut it was from thirteen to fifteen feet tall, and was beginning to glaze.

1591, *Corn stover.*—Analyzed in connection with cow feeding experiments Nos. 35 and 37.

1618, *Corn stover.*—Analyzed in connection with cow feeding experiments Nos. 36 and 38.

1736–1745, *Stover of yellow flint corn.*—Grown by Station in 1896. (For further description see page 206.) Nos. 1736 and 1737 were from plots without fertilizers. Nos. 1738 and 1739 were from plots to which there were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds. Nos. 1740, 1741, and 1742 were grown on plots to which mixed minerals were applied, as in 1738 and 1739, and had in addition 160, 320, and 480 pounds of nitrate of soda per acre respectively. Nos. 1743, 1744, and 1745 were grown on plots to which mixed minerals were applied, as in 1738 and 1739, and had in addition 120, 240, and 360 pounds of sulphate of ammonia per acre respectively.

1746–1755, *Stover of white flint corn.*—Grown by the Station in 1896. (For further description see page 206.) Nos. 1746 and 1747 were from plots without fertilizers. Nos. 1748 and 1749 were from plots to which there were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds per acre. Nos. 1750, 1751, and 1752 were grown on plots to which mixed minerals were applied, as in 1748 and 1749, and had in addition 160, 320, and 480 pounds of nitrate of soda per acre respectively. Nos. 1753, 1754, and 1755 were grown on plots to which mixed minerals were applied, as in 1748 and 1749, and had in addition 120, 240, and 360 pounds of sulphate of ammonia per acre respectively.

CURED HAYS AND ROWEN.

1593, *Clover hay.*—Used in cow feeding experiment No. 37.

1622, 1623, *Clover rowen.*—Field cured and barn cured respectively. Used in sheep digestion experiments Nos. 28 and 29.

1617, *Hay.*—Second quality from fine meadow grasses. Used in cow feeding experiments Nos. 36 and 38.

1621, *Millet and Hungarian hay.*—Half-and-half. Used in cow feeding experiments Nos. 36 and 38.

1592, *Oat hay.*—Used in cow feeding experiment No. 35.

1613, *Oat hay.*

1625, *Oat hay.*—Cut when about two-thirds grown. Used in sheep digestion experiment No. 31.

1599, *Swamp hay.*

1624, 1641, 1642, *Fine rowen hay.*—From mixed grasses. Grown by the Station, and used in sheep digestion experiments Nos. 30, 32, and 33 respectively.

SPECIAL NITROGEN EXPERIMENT.

In the year 1895 the Station began a series of field experiments on the effects of nitrogenous fertilizers on the yield and composition of corn, cow pea fodder, and soy bean seed. Samples of the seeds, the fodder, or the stover were taken from the various plots at the time of harvest, and have, in most cases, been analyzed. Samples 1718–1726, 1731 of cow pea fodder, and samples 1736–1745 and 1746–1755 of corn stovers, and the two lots of flint corn, 1756–1765 and 1766–1775, described below, represent samples taken in connection with this experiment. For a full description of the experiment, see pages 101–106 of the Eighth Annual Report, and page 205 of this Report.

SEEDS.

1756–1765, *Yellow flint corn.*—Grown by the Station in 1896. Nos. 1756 and 1757 were from plots without fertilizers. Nos. 1758 and 1759 were from plots to which were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds per acre. Nos. 1760, 1761, and 1762 were grown on plots to which mixed minerals were applied, as in 1758 and 1759, and had in addition 160, 320, and 480 pounds of nitrate of soda per acre respectively. Nos. 1763, 1764, and 1765 were grown on plots to which mixed minerals were applied, as in 1758 and 1759, and had in addition 120, 240, and 360 pounds of sulphate of ammonia per acre respectively.

1766–1775, *White flint corn.*—Grown by the Station in 1896. Nos. 1766 and 1767 were from plots without fertilizers. Nos. 1768 and 1769 were from plots to which there were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds per acre. Nos. 1770, 1771, and 1772 were grown on plots to which mixed minerals were applied, as in 1768 and 1769, and had in addition 160, 320, and 480 pounds of nitrate of

soda per acre respectively. Nos. 1773, 1774, and 1775 were grown on plots to which mixed minerals were applied, as in 1768 and 1769, and had in addition 120, 240, and 360 pounds of sulphate of ammonia per acre respectively.

1706–1717, *Oats.*—Grown by the Station in 1896 in rotation soil test. (See page 213 of this Report.) The plots have received the same kinds and amounts of fertilizers for the past eight years. Nos. 1715, 1716, and 1717 were from plots without fertilizers. No. 1706 was from a plot to which 160 pounds per acre of nitrate of soda had been applied. No. 1707 was from a plot to which 320 pounds per acre of dissolved bone-black had been applied. No. 1708 grew on a plot which had received at the rate of 160 pounds of muriate of potash per acre. No. 1709 was from a plot receiving both nitrate of soda, as 1706, and dissolved bone-black, as 1707. The plot on which 1710 was grown received both nitrate of soda, as 1706, and muriate of potash, as 1708. No. 1711 was grown with dissolved bone-black, as 1707, and muriate of potash, as 1708, while 1712 received all three forms of fertilizer, as 1706, 1707, 1708. No. 1714 was from a plot receiving stable manure, and 1713 from a plot receiving stable manure and dissolved bone-black, 160 pounds per acre.

MILLING AND BY-PRODUCTS.

1588, *Corn meal.*—Made from Western grown corn. Used in cow feeding experiment No. 35.

1598, *Corn meal.*

1620, *Corn meal.*—With a small amount of cob. Used in feeding experiments with cows, Nos. 36 and 38.

1615, *Buffalo gluten feed.*—Used in feeding experiments, Nos. 36 and 38, with cows.

1594, *Chicago gluten meal.*—Used in feeding experiment, No. 37, with cows.

1614, *Chicago gluten meal.*

1616, *Linseed oil meal.*—Used in cow feeding experiments, Nos. 36 and 38.

1590, 1595, *Wheat bran.*—Used in feeding experiments with cows, Nos. 35 and 37.

1597, *Wheat bran.*

1603, 1604, *Wheat bran.*—From winter wheat and spring wheat respectively.

1619, *Wheat bran.*—Used in feeding experiments, Nos. 36 and 38, with cows.

1643, *Wheat bran (coarse).*—Used in sheep digestion experiment No. 32.

1589, *Wheat middlings.*—Used in feeding experiments, Nos. 35 and 37, with cows.

1601, 1602, *Wheat middlings.*—From winter wheat and spring wheat respectively.

1644, *Wheat middlings (No. 2).*—Used in sheep digestion experiment No. 33.

TABLE 73.

Composition of fodders and feeding stuffs analyzed 1895–96. Calculated to water content at time of taking sample.

Lab. No.	FEEDING STUFFS.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Green Fodders.	%	%	%	%	%	%	Cal.
1649	Timothy, - - -	62.40	3.20	1.68	19.33	10.99	2.40	695
1654	Timothy, - - -	61.40	2.47	1.28	19.95	12.62	2.28	705
1659	Timothy, - - -	63.62	2.48	1.08	18.49	12.26	2.07	665
1664	Timothy, - - -	63.69	2.86	1.14	18.85	11.66	1.80	665
	Average (4), - -	**62.78**	**2.75**	**1.30**	**19.15**	**11.88**	**2.14**	**685**
	Avg. all analyses (16),	**68.60**	**2.60**	**1.00**	**15.30**	**10.50**	**2.00**	**570**
1650	Orchard grass, - -	66.02	3.43	1.78	14.83	10.70	3.24	615
1655	Orchard grass, - -	66.63	3.18	1.68	14.24	10.81	3.46	595
1660	Orchard grass, - -	71.49	2.87	1.32	11.36	10.10	2.86	505
1665	Orchard grass, - -	72.87	3.21	1.46	11.54	8.59	2.33	495
	Average (4), - -	**69.26**	**3.17**	**1.56**	**12.99**	**10.05**	**2.97**	**560**
	Avg. all analyses (16),	**68.60**	**3.00**	**1.30**	**13.60**	**10.70**	**2.80**	**565**
1651	Meadow fescue, -	65.27	3.25	1.69	16.87	10.00	2.92	630
1656	Meadow fescue, -	66.28	3.12	1.30	16.89	9.77	2.64	610
1661	Meadow fescue, -	69.22	3.10	1.20	15.17	8.68	2.63	550
1666	Meadow fescue, -	72.57	3.45	1.35	12.12	8.31	2.20	500
	Average (4), - -	**68.33**	**3.23**	**1.39**	**15.26**	**9.19**	**2.60**	**575**
	Avg. all analyses (14),	**71.60**	**2.50**	**1.00**	**13.00**	**9.80**	**2.10**	**515**
1652	Bromus inermis, -	63.63	2.92	1.26	18.94	10.49	2.76	655
1657	Bromus inermis, -	64.35	2.88	1.21	18.43	9.92	3.21	630
1662	Bromus inermis, -	66.07	3.19	1.19	17.24	9.68	2.63	610
1667	Bromus inermis, -	70.09	4.00	1.27	13.37	9.07	2.20	545
	Avg. all analyses (4),	**66.04**	**3.25**	**1.23**	**16.99**	**9.79**	**2.70**	**610**
1653	Red-top, - - -	56.54	2.91	1.41	23.12	12.86	3.16	780
1658	Red-top, - - -	58.93	2.72	1.35	21.90	12.46	2.64	745
1663	Red-top, - - -	62.74	3.06	1.39	19.53	10.72	2.56	680
1668	Red-top, - - -	61.53	3.80	1.34	20.05	10.92	2.36	705
	Avg. all analyses (4),	**59.94**	**3.12**	**1.37**	**21.15**	**11.74**	**2.68**	**730**
1675	Millet fodder, - -	75.49	2.03	.91	12.07	7.26	2.24	435
1696	Millet fodder, - -	75.59	1.73	.61	12.21	7.78	2.08	430
1677	Millet fodder, - -	66.51	2.12	1.36	17.67	10.08	2.26	615
1701	Millet fodder, - -	71.09	1.22	.72	15.73	9.22	2.02	515
	Avg. all analyses (4),	**72.17**	**1.77**	**.90**	**14.42**	**8.59**	**2.15**	**500**
1703	Cow pea fodder, -	84.03	2.81	.57	6.92	3.77	1.90	275
1705	Cow pea fodder, -	84.74	2.97	.57	6.31	3.57	1.84	265
1718	Cow pea fodder, -	81.72	3.08	.53	7.86	4.61	2.20	310
1719	Cow pea fodder, -	79.08	4.19	.82	9.40	3.97	2.54	360
1720	Cow pea fodder, -	84.89	2.97	.54	6.25	3.41	1.94	260
1721	Cow pea fodder, -	82.57	3.18	.50	7.81	3.92	2.02	300
1722	Cow pea fodder, -	82.33	2.97	.53	8.15	4.06	1.96	305
1723	Cow pea fodder, -	82.90	3.23	.49	7.43	3.88	2.07	290
1724	Cow pea fodder, -	83.46	3.15	.51	6.89	4.03	1.96	285
1725	Cow pea fodder, -	82.76	2.86	.47	7.95	4.09	1.87	300
1726	Cow pea fodder, -	85.27	3.15	.39	5.66	3.57	1.96	245
1731	Cow pea fodder, -	83.44	3.23	.62	7.41	3.38	1.92	285
	Average (12), - -	**83.10**	**3.15**	**.54**	**7.34**	**3.85**	**2.02**	**290**
	Avg. all analyses (49),	**83.00**	**3.00**	**.60**	**7.70**	**3.70**	**2.00**	**295**

TABLE 73.—(*Continued.*)

Lab. No.	Feeding Stuffs.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Green Fodders.	%	%	%	%	%	%	Cal.
1669	Oat fodder, - -	67.16	3.47	1.46	15.70	9.71	2.50	600
1670	Oat fodder, - -	66.95	3.05	1.46	16.35	9.88	2.31	605
1673	Oat fodder, - -	74.04	2.60	1.09	11.65	8.45	2.17	470
1674	Oat fodder, - -	73.03	2.84	1.15	12.72	8.20	2.06	490
	Average (4), - -	**70.29**	**2.99**	**1.29**	**14.11**	**9.06**	**2.26**	**540**
	Avg. all analyses (6),	**73.60**	**2.90**	**1.20**	**12.30**	**7.80**	**2.20**	**480**
1671	Oat and pea fodder, -	68.83	4.00	1.57	15.12	8.28	2.20	575
1672	Oat and pea fodder, -	71.41	4.68	1.30	10.63	9.94	2.04	525
	Average (2), - -	**70.12**	**4.34**	**1.43**	**12.88**	**9.11**	**2.12**	**550**
	Avg. all analyses (7),	**79.90**	**3.60**	**1.00**	**8.30**	**5.50**	**1.70**	**365**
1704	Rowen, - - -	75.68	3.51	1.39	11.32	6.16	1.94	450
1728	Rowen, - - -	70.24	4.02	1.57	13.61	8.05	2.51	545
	Average (2), - -	**72.96**	**5.76**	**1.48**	**12.47**	**7.11**	**2.22**	**500**
	Avg. all analyses (10),	**77.70**	**3.70**	**1.00**	**9.60**	**6.00**	**2.00**	**400**
1702	Sweet corn fodder, -	82.76	1.69	.49	10.41	3.56	1.09	310
1727	Sweet corn fodder, -	79.43	1.94	.53	12.23	4.64	1.23	370
1729	Sweet corn fodder, -	82.64	1.84	.47	9.87	4.03	1.15	315
1730	Sweet corn fodder, -	81.02	1.84	.62	10.92	4.45	1.15	345
	Average (4), - -	**81.46**	**1.83**	**.53**	**10.86**	**4.17**	**1.15**	**335**
	Avg. all analyses (6),	**80.80**	**1.80**	**.50**	**11.40**	**4.30**	**1.20**	**345**
1697	Soy bean fodder, -	79.51	3.15	.66	7.97	6.39	2.32	355
1698	Soy bean fodder, -	77.12	3.27	.87	8.70	7.61	2.43	400
1676	Soy bean fodder, -	75.96	3.80	1.22	10.58	6.03	2.41	430
1699	Soy bean fodder, -	77.42	3.56	.93	8.64	7.16	2.29	400
1700	Soy bean fodder, -	75.78	2.69	.92	11.77	6.50	2.34	430
	Average (5), - -	**77.16**	**3.29**	**.92**	**9.53**	**6.74**	**2.36**	**405**
	Avg. all analyses (13),	**76.50**	**3.60**	**1.00**	**10.10**	**6.50**	**2.30**	**420**
	Ensilage.							
1596	Ensilage, - - -	53.36	3.14	1.46	30.59	9.38	2.07	865
1600	Corn ensilage, - -	75.98	1.75	.67	13.97	6.34	1.29	440
	Avg. all analyses (14),	**75.40**	**1.90**	**.90**	**14.00**	**6.40**	**1.40**	**455**
	Cured Fodders.							
1591	Corn stover, - -	11.37	6.47	2.06	43.84	29.57	6.69	1575
1618	Corn stover, - -	27.61	3.19	1.13	36.08	26.33	5.66	1265
1736	Corn stover, - -	43.69	4.36	.70	29.34	17.61	4.30	985
1737	Corn stover - -	46.15	3.60	1.07	24.90	20.32	3.96	955
1738	Corn stover, - -	43.78	3.01	1.18	27.62	20.32	4.09	1000
1739	Corn stover, - -	43.63	2.85	1.28	28.25	19.87	4.12	1005
1740	Corn stover, - -	42.29	3.04	1.15	26.68	22.90	3.94	1030
1741	Corn stover, - -	46.39	3.71	.99	25.09	19.88	3.94	950
1742	Corn stover, - -	40.19	4.21	1.14	27.99	21.95	4.52	1055
1743	Corn stover, - -	42.36	3.14	1.31	28.04	20.89	4.26	1025
1744	Corn stover, - -	53.66	2.89	.86	22.77	16.46	3.36	820
1745	Corn stover, - -	48.76	4.38	.99	24.93	17.05	3.89	905
1746	Corn stover, - -	16.51	6.12	1.49	40.60	28.88	6.40	1470
1747	Corn stover, - -	17.35	5.27	1.37	41.22	28.84	5.95	1460
1748	Corn stover, - -	22.93	3.68	1.63	39.49	25.76	6.51	1350
1749	Corn stover, - -	25.12	3.38	1.31	37.04	26.98	6.17	1310
1750	Corn stover, - -	22.37	3.79	1.69	40.14	25.85	6.16	1370

TABLE 73.—*(Continued.)*

Lab. No.	Feeding Stuffs.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Cured Fodders.	%	%	%	%	%	%	Cal.
1751	Corn stover, - -	25.50	4.45	1.48	36.40	26.75	5.42	1320
1752	Corn stover, - -	22.55	6.43	1.51	39.38	24.46	5.67	1390
1753	Corn stover, - -	29.36	3.32	1.55	35.81	23.82	6.14	1235
1754	Corn stover, - -	31.45	3.98	1.43	34.17	23.14	5.83	1200
1755	Corn stover, - -	30.67	4.84	1.25	32.11	25.90	5.23	1220
	Average (22), - -	**33.35**	**4.10**	**1.30**	**32.81**	**23.34**	**5.10**	**1175**
	Avg. all analyses (174),	**41.60**	**3.60**	**1.20**	**29.80**	**20.00**	**3.80**	**1045**
	Cured Hays and Rowen.							
1593	Clover hay, - -	6.44	14.63	2.24	38.70	31.86	6.13	1675
1622	Clover rowen, - -	15.13	15.64	3.61	37.36	21.02	7.24	1530
1623	Clover rowen, - -	14.56	17.39	3.82	37.20	19.68	7.35	1545
	Average (2), - -	**14.84**	**16.52**	**3.72**	**37.28**	**20.35**	**7.29**	**1540**
	Avg. all analyses (6),	**11.20**	**15.50**	**3.50**	**39.10**	**23.90**	**6.80**	**1610**
1617	Hay, 2d quality, -	5.89	11.75	2.41	44.07	31.15	4.73	1720
	Avg. all analyses (3),	**11.00**	**9.40**	**2.80**	**42.80**	**28.50**	**5.50**	**1620**
1621	Hay, millet and Hungarian), - - -	6.65	6.47	2.20	44.44	35.02	5.22	1690
1592	Hay, oat, - - -	8.16	7.85	3.59	44.87	29.59	5.94	1685
1613	Hay, oat, - - -	5.55	8.13	2.71	45.88	32.38	5.35	1720
1625	Hay, oat, - - -	12.25	9.79	4.14	42.48	25.79	5.55	1625
	Average (3), - -	**8.65**	**8.59**	**3.48**	**44.41**	**29.26**	**5.61**	**1675**
	Avg. all analyses (12),	**11.60**	**8.40**	**3.30**	**43.40**	**27.90**	**5.40**	**1620**
1599	Hay, swamp, - -	6.30	9.06	3.09	48.91	26.17	6.47	1695
	Avg. all analyses (3),	**8.10**	**9.60**	**3.30**	**46.00**	**26.80**	**6.20**	**1670**
1624	Hay, fine rowen, -	10.51	14.40	4.43	42.91	21.08	6.67	1645
1641	Hay, fine rowen, -	13.24	13.54	4.93	40.14	20.64	7.51	1590
1642	Hay, fine rowen, -	8.84	13.06	4.81	44.25	22.02	7.02	1680
	Average (3), - -	**10.86**	**13.67**	**4.72**	**42.43**	**21.25**	**7.07**	**1640**
	Avg. all analyses (41),*	**13.00**	**9.20**	**3.20**	**42.30**	**26.80**	**5.50**	**1590**
	Seeds.							
1756	Corn, - - -	28.40	7.09	4.16	57.71	1.49	1.15	1410
1757	Corn, - - -	26.92	7.47	4.27	58.61	1.40	1.33	1435
1758	Corn, - - -	27.00	6.80	4.53	58.88	1.48	1.31	1440
1759	Corn, - - -	26.81	6.86	4.30	59.29	1.49	1.25	1440
1760	Corn, - - -	29.54	6.58	3.95	57.89	.96	1.08	1385
1761	Corn. - - -	29.14	7.62	4.14	56.92	.98	1.20	1390
1762	Corn, - - -	28.26	8.38	4.50	56.54	1.05	1.27	1420
1763	Corn, - - -	25.26	7.63	5.07	59.47	1.19	1.38	1485
1764	Corn, - - -	29.09	6.99	4.95	56.48	1.12	1.37	1410
1765	Corn, - - -	22.68	8.60	4.76	61.56	1.02	1.38	1525
1766	Corn, - - -	16.10	9.34	4.58	67.24	1.24	1.50	1640
1767	Corn, - - -	24.99	8.41	3.90	60.21	1.21	1.28	1465
1768	Corn, - - -	15.47	8.10	4.53	69.31	1.12	1.47	1650
1769	Corn, - - -	22.54	7.61	4.13	63.54	.94	1.24	1515
1770	Corn, - - -	20.81	8.06	4.67	63.80	1.07	1.59	1555
1771	Corn, - - -	21.09	8.99	5.31	61.74	1.37	1.50	1565
1772	Corn, - - -	21.33	9.80	4.46	61.73	1.26	1.42	1545
1773	Corn, - - -	22.02	8.51	4.34	62.86	.98	1.29	1525
1774	Corn, - - -	21.15	8.64	5.16	62.25	1.21	1.59	1560

TABLE 73.—(*Concluded.*)

Lab. No.	FEEDING STUFFS.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Seeds.	%	%	%	%	%	%	Cal.
1775	Corn, - - -	22.03	9.38	4.96	61.09	1.01	1.53	1540
	Average (20), - -	**24.03**	**8.04**	**4.53**	**60.86**	**1.18**	**1.36**	**1495**
	Avg. all analyses (173),	**18.90**	**9.00**	**4.70**	**64.70**	**1.30**	**1.40**	**1595**
1706	Oats, - - -	9.07	13.50	5.96	61.94	6.58	2.95	1775
1707	Oats, - - -	8.17	11.31	5.93	63.33	7.96	3.30	1785
1708	Oats, - - -	9.28	11.50	5.70	62.20	8.27	3.05	1765
1709	Oats, - - -	8.25	11.69	5.83	64.74	6.72	2.77	1790
1710	Oats, - - -	8.41	12.94	5.97	62.98	6.97	2.73	1790
1711	Oats, - - -	10.05	10.81	5.80	63.89	6.73	2.72	1760
1712	Oats, - - -	7.33	11.02	5.60	64.21	9.06	2.78	1805
1713	Oats, - - -	7.81	11.13	5.50	63.64	9.02	2.90	1790
1714	Oats, - - -	8.59	11.69	5.64	64.74	6.64	2.70	1780
1715	Oats, - - -	10.94	11.73	5.65	61.28	7.58	2.82	1735
1716	Oats, - - -	9.98	11.62	5.63	61.19	8.46	3.12	1750
1717	Oats, - - -	8.58	12.00	5.40	62.08	8.93	3.01	1770
	Average (12), - -	**8.87**	**11.75**	**5.72**	**63.02**	**7.74**	**2.90**	**1775**
	Avg. all analyses (50),	**12.80**	**12.70**	**5.20**	**58.10**	**8.50**	**2.70**	**1695**
	Milling and By-Products.							
1588	Corn meal, - -	11.98	9.19	5.46	70.00	1.79	1.58	1735
1598	Corn meal, - -	11.48	10.69	5.37	69.16	1.84	1.46	1750
1620	Corn meal, - -	10.78	10.15	4.55	70.75	2.20	1.57	1740
	Average (3), - -	**11.41**	**10.01**	**5.13**	**69.97**	**1.94**	**1.54**	**1740**
	Avg. all analyses (23),	**12.90**	**9.60**	**4.50**	**69.90**	**1.60**	**1.50**	**1700**
1615	Buffalo gluten feed, -	8.23	26.75	5.25	52.54	5.53	1.70	1800
	Avg. all analyses (6),	**8.60**	**22.60**	**12.00**	**49.60**	**6.10**	**1.10**	**1965**
1594	Chicago gluten meal, -	9.56	33.02	7.74	45.03	3.93	.72	1850
1614	Chicago gluten meal, -	8.10	43.13	5.27	40.37	2.21	.92	1820
	Average (2), - -	**8.83**	**38.08**	**6.50**	**42.70**	**3.07**	**.82**	**1835**
	Avg. all analyses (7),	**8.70**	**35.40**	**6.30**	**45.90**	**2.70**	**1.00**	**1830**
1616	Linseed oil meal, -	8.00	38.44	6.74	32.93	8.63	5.26	1770
	Avg. all analyses (10),	**10.30**	**33.80**	**5.30**	**37.40**	**7.60**	**5.60**	**1690**
1590	Wheat bran, - -	8.73	18.00	4.97	54.92	7.70	5.68	1710
1595	Wheat bran, - -	8.45	17.44	4.55	55.02	9.13	5.41	1710
1597	Wheat bran, - -	9.75	17.62	5.56	52.97	8.95	5.15	1715
1603	Wheat bran, winter, -	7.94	17.75	4.32	54.90	8.78	6.31	1695
1604	Wheat bran, spring, -	7.77	17.31	5.58	54.54	9.56	5.24	1750
1619	Wheat bran, - -	6.77	18.06	4.67	57.39	7.97	5.14	1750
1643	Wheat bran, coarse, -	7.05	15.25	5.44	55.08	11.12	6.06	1745
	Average (7), - -	**8.07**	**17.35**	**5.01**	**54.97**	**9.03**	**5.57**	**1725**
	Avg. all analyses (38),	**9.40**	**17.20**	**5.10**	**53.70**	**9.10**	**5.50**	**1705**
1589	Wheat middlings, -	9.93	17.00	3.96	63.89	2.78	2.44	1725
1601	Wheat middl'gs, winter,	9.27	18.13	3.83	60.20	5.30	3.27	1715
1602	Wheat middl'gs, spring,	10.47	20.13	5.57	52.73	6.65	4.45	1715
1644	Wheat middlings, -	8.41	18.69	5.79	52.54	9.60	4.97	1745
	Average (4), - -	**9.52**	**18.49**	**4.79**	**57.34**	**6.08**	**3.78**	**1725**
	Avg. all analyses (16),	**10.30**	**18.30**	**5.10**	**56.30**	**6.00**	**4.00**	**1715**

* These include hay from mixed grasses as well as rowen from mixed grasses.

TABLE 74.

Composition of water-free substance of fodders and feeding stuffs analyzed 1895–96.

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Green Fodders.	%	%	%	%	%	Cal.
1649	Timothy, - - - -	8.51	4.46	51.42	29.22	6.39	1850
1654	Timothy, - - - -	6.41	3.32	51.68	32.68	5.91	1830
1659	Timothy, - - - -	6.82	2.95	50.82	33.71	5.70	1825
1664	Timothy, - - - -	7.89	3.13	51.91	32.12	4.95	1840
	Average (4), - - -	**7.41**	**3.46**	**51.46**	**31.93**	**5.74**	**1835**
	Average all analyses (16),	**8.52**	**3.22**	**48.39**	**33.61**	**6.26**	**1820**
1650	Orchard grass, - - -	10.09	5.25	43.65	31.47	9.54	1810
1655	Orchard grass, - - -	9.53	5.03	42.67	32.40	10.37	1785
1660	Orchard grass, - - -	10.07	4.62	39.85	35.43	10.03	1780
1665	Orchard grass, - - -	11.83	5.38	42.55	31.67	8.57	1830
	Average (4), - - -	**10.38**	**5.07**	**42.18**	**32.74**	**9.63**	**1800**
	Average all analyses (16),	**9.74**	**4.25**	**43.23**	**33.92**	**8.86**	**1800**
1651	Meadow fescue, - - -	9.36	4.85	48.59	28.79	8.41	1820
1656	Meadow fescue, - - -	9.24	3.86	50.10	28.97	7.83	1810
1661	Meadow fescue, - - -	10.07	3.90	49.29	28.20	8.54	1810
1666	Meadow fescue, - - -	12.59	4.94	44.17	30.29	8.01	1825
	Average (4), - - -	**10.31**	**4.39**	**48.04**	**29.06**	**8.20**	**1815**
	Average all analyses (14),	**9.02**	**3.30**	**45.31**	**34.69**	**7.68**	**1795**
1652	Bromus inermis, - - -	8.02	3.48	52.06	28.84	7.60	1800
1657	Bromus inermis, - - -	8.09	3.38	51.70	27.83	9.00	1775
1662	Bromus inermis, - - -	9.39	3.51	50.82	28.52	7.76	1800
1667	Bromus inermis, - - -	13.38	4.25	44.71	30.33	7.33	1825
	Average all analyses (4), -	**9.72**	**3.66**	**49.82**	**28.88**	**7.92**	**1800**
1653	Red-top, - - - -	6.70	3.23	53.19	29.60	7.28	1800
1658	Red-top, - - - -	6.62	3.30	53.32	30.34	6.42	1820
1663	Red-top, - - - -	8.20	3.74	52.42	28.76	6.88	1820
1668	Red-top, - - - -	9.86	3.50	52.11	28.39	6.14	1830
	Average all analyses (4), -	**7.85**	**3.44**	**52.76**	**29.27**	**6.68**	**1815**
1675	Millet fodder, - - -	8.27	3.73	49.26	29.63	9.11	1780
1696	Millet fodder, - - -	7.09	2.51	50.05	31.87	8.48	1760
1677	Millet fodder, - - -	6.34	4.04	52.76	30.12	6.74	1830
1701	Millet fodder, - - -	4.22	2.48	54.41	31.91	6.98	1790
	Average all analyses (4), -	**6.48**	**3.19**	**51.62**	**30.88**	**7.83**	**1790**
1703	Cow pea fodder, - - -	17.58	3.54	43.34	23.61	11.93	1720
1705	Cow pea fodder, - - -	19.44	3.71	41.36	23.39	12.10	1725
1718	Cow pea fodder, - - -	16.82	2.92	42.99	25.23	12.04	1705
1719	Cow pea fodder, - - -	20.03	3.91	44.95	18.96	12.15	1725
1720	Cow pea fodder, - - -	19.66	3.59	41.40	22.55	12.80	1710
1721	Cow pea fodder, - - -	18.23	2.87	44.84	22.48	11.58	1710
1722	Cow pea fodder, - - -	16.81	2.98	46.15	22.97	11.09	1725
1723	Cow pea fodder, - - -	18.90	2.88	43.44	22.67	12.11	1705
1724	Cow pea fodder, - - -	19.02	3.07	41.67	24.39	11.85	1715
1725	Cow pea fodder, - - -	16.61	2.71	46.10	23.70	10.88	1720
1726	Cow pea fodder, - - -	21.39	2.63	38.43	24.25	13.30	1670
1731	Cow pea fodder, - - -	19.49	3.76	44.72	20.41	11.62	1730
	Average (12), - - -	**18.67**	**3.22**	**43.28**	**22.88**	**11.95**	**1715**
	Average all analyses (49),	**18.09**	**3.47**	**44.74**	**22.15**	**11.55**	**1730**

TABLE 74.—*(Continued.)*

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Green Fodders.	%	%	%	%	%	Cal.
1669	Oat fodder, - - -	10.56	4.46	47.80	29.57	7.61	1825
1670	Oat fodder, - - -	9.24	4.43	49.45	29.90	6.98	1835
1673	Oat fodder, - - -	10.00	4.20	44.88	32.57	8.35	1805
1674	Oat fodder, - - -	10.52	4.27	47.17	30.42	7.62	1820
	Average (4), - - -	**10.08**	**4.34**	**47.33**	**30.61**	**7.64**	**1820**
	Average all analyses (6), -	**11.28**	**4.62**	**46.32**	**29.44**	**8.34**	**1810**
1671	Oat and pea fodder, - -	12.84	5.03	48.51	26.55	7.07	1845
1672	Oat and pea fodder, - -	16.38	4.55	37.16	34.78	7.13	1835
	Average (2), - - -	**14.61**	**4.79**	**42.84**	**30.66**	**7.10**	**1840**
	Average all analyses (7), -	**18.92**	**5.01**	**40.61**	**26.69**	**8.77**	**1810**
1704	Rowen, - - - -	14.45	5.71	46.55	25.34	7.95	1845
1728	Rowen, - - - -	13.50	5.29	45.71	27.05	8.45	1830
	Average (2), - - -	**13.98**	**5.50**	**46.13**	**26.19**	**8.20**	**1840**
	Average all analyses (10),	**17.09**	**4.03**	**42.64**	**27.05**	**9.19**	**1785**
1702	Sweet corn fodder, - -	9.80	2.87	60.38	20.63	6.32	1810
1727	Sweet corn fodder, - -	9.41	2.57	59.48	22.58	5.96	1810
1729	Sweet corn fodder, - -	10.62	2.70	56.87	23.19	6.62	1800
1730	Sweet corn fodder, - -	9.68	3.24	57.58	23.44	6.06	1825
	Average (4), - - -	**9.88**	**2.84**	**58.58**	**22.46**	**6.24**	**1810**
	Average all analyses (6), -	**9.35**	**2.85**	**59.31**	**22.32**	**6.17**	**1815**
1697	Soy bean fodder, - -	15.37	3.25	38.88	31.18	11.32	1725
1698	Soy bean fodder, - -	14.28	3.81	38.03	33.28	10.60	1755
1676	Soy bean fodder, - -	15.80	5.05	44.04	25.06	10.05	1795
1699	Soy bean fodder, - -	15.77	4.10	38.30	31.72	10.11	1770
1700	Soy bean fodder, - -	11.13	3.79	48.62	26.82	9.64	1770
	Average (5), - - -	**14.47**	**4.00**	**41.58**	**29.61**	**10.34**	**1765**
	Average all analyses (13),	**15.26**	**4.09**	**43.04**	**27.57**	**10.04**	**1770**
	Ensilage.						
1596	Ensilage, - - - -	6.73	3.13	65.59	20.10	4.45	1850
1600	Corn ensilage, - - -	7.28	2.79	58.15	26.41	5.37	1830
	Average all analyses (14),	**7.88**	**3.53**	**55.31**	**27.45**	**5.83**	**1835**
	Cured Fodders.						
1591	Corn stover, - - -	7.30	2.33	49.46	33.36	7.55	1775
1618	Corn stover, - - -	4.40	1.56	49.84	36.38	7.82	1750
1736	Corn stover, - - -	7.75	1.24	52.10	31.27	7.64	1745
1737	Corn stover, - - -	6.70	1.98	46.23	37.72	7.37	1770
1738	Corn stover, - - -	5.37	2.11	49.12	36.13	7.27	1775
1739	Corn stover, - - -	5.07	2.27	50.11	35.24	7.31	1775
1740	Corn stover, - - -	5.28	2.00	46.22	39.67	6.83	1780
1741	Corn stover, - - -	6.91	1.85	46.80	37.08	7.36	1770
1742	Corn stover, - - -	7.04	1.92	46.80	36.69	7.55	1765
1743	Corn stover, - - -	5.45	2.27	48.66	36.24	7.38	1780
1744	Corn stover, - - -	6.25	1.86	49.13	35.51	7.25	1770
1745	Corn stover, - - -	8.54	1.94	48.65	33.27	7.60	1765
1746	Corn stover, - - -	7.33	1.79	48.63	34.59	7.66	1760
1747	Corn stover, - - -	6.37	1.66	49.87	34.90	7.20	1765
1748	Corn stover, - - -	4.77	2.11	51.24	33.43	8.45	1750
1749	Corn stover, - - -	4.52	1.75	49.46	36.03	8.24	1750
1750	Corn stover, - - -	4.89	2.17	51.70	33.30	7.94	1765

TABLE 74.—(*Continued.*)

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Cured Fodders.	%	%	%	%	%	Cal.
1751	Corn stover, - - -	5.97	1.99	48.85	35.91	7.28	1770
1752	Corn stover, - - -	8.30	1.95	50.84	31.59	7.32	1770
1753	Corn stover, - - -	4.70	2.20	50.70	33.71	8.69	1750
1754	Corn stover, - - -	5.81	2.08	49.85	33.75	8.51	1750
1755	Corn stover, - - -	6.99	1.81	46.31	37.36	7.53	1765
	Average (22), - - -	**6.17**	**1.95**	**49.12**	**35.15**	**7.61**	**1765**
	Average all analyses (174),	**6.40**	**1.98**	**51.04**	**34.19**	**6.29**	**1790**
	Cured Hays and Rowen.						
1593	Clover hay, - - -	15.64	2.40	41.36	34.05	6.55	1795
	Average all analyses (6), -	**17.55**	**3.92**	**43.98**	**26.92**	**7.63**	**1810**
1622	Clover rowen, - - -	18.43	4.26	44.02	24.77	8.52	1800
1623	Clover rowen, - - -	20.36	4.47	43.54	23.03	8.60	1865
	Average all analyses (6), -	**19.39**	**4.37**	**43.78**	**23.90**	**8.56**	**1835**
1617	Hay, second quality, - -	12.48	2.56	46.83	33.10	5.03	1830
	Average all analyses (3), -	**10.47**	**3.17**	**48.17**	**31.90**	**6.29**	**1810**
1621	Hay, millet and Hungarian,	6.93	2.35	47.61	37.51	5.60	1815
1592	Hay, oat, - - - -	8.55	3.91	48.85	32.22	6.47	1830
1613	Hay, oat, - - - -	8.61	2.87	48.58	34.28	5.66	1825
1625	Hay, oat, - - - -	11.16	4.72	48.42	29.38	6.32	1855
	Average (3), - - -	**9.44**	**3.83**	**48.62**	**31.96**	**6.15**	**1835**
	Average all analyses (12),	**9.54**	**3.79**	**49.21**	**31.42**	**6.04**	**1840**
1599	Hay, swamp, - - -	9.67	3.30	52.20	27.93	6.90	1810
	Average all analyses (3), -	**10.45**	**3.65**	**50.00**	**29.19**	**6.71**	**1820**
1624	Hay, fine rowen, - -	16.09	4.94	47.95	23.56	7.46	1840
1641	Hay, fine rowen, - -	15.60	5.68	46.27	23.79	8.66	1835
1642	Hay, fine rowen, - -	14.33	5.28	48.54	24.15	7.70	1840
	Average (3), - - -	**15.34**	**5.30**	**47.59**	**23.83**	**7.94**	**1840**
	Average all analyses (41),*	**10.72**	**3.59**	**48.62**	**30.69**	**6.38**	**1825**
	Seeds.						
1756	Corn, - - - - - -	9.90	5.81	80.60	2.08	1.61	1965
1757	Corn, - - - - - -	10.22	5.84	80.20	1.92	1.82	1960
1758	Corn, - - - - - -	9.31	6.21	80.66	2.03	1.79	1970
1759	Corn, - - - - - -	9.38	5.88	81.01	2.03	1.70	1970
1760	Corn, - - - - - -	9.34	5.60	82.16	1.36	1.54	1965
1761	Corn, - - - - - -	10.76	5.85	80.31	1.39	1.69	1970
1762	Corn, - - - - - -	11.68	6.28	78.81	1.46	1.77	1975
1763	Corn, - - - - - -	10.20	6.79	79.56	1.60	1.85	1985
1764	Corn, - - - - - -	9.87	6.98	79.64	1.58	1.93	1990
1765	Corn, - - - - - -	11.13	6.16	79.62	1.31	1.78	1975
1766	Corn, - - - - - -	11.14	5.46	80.14	1.47	1.79	1955
1767	Corn, - - - - - -	11.21	5.20	80.27	1.61	1.71	1950
1768	Corn, - - - - - -	9.58	5.35	82.00	1.33	1.74	1955
1769	Corn, - - - - - -	9.82	5.34	82.03	1.21	1.60	1955
1770	Corn, - - - - - -	10.17	5.89	80.58	1.35	2.01	1960
1771	Corn, - - - - - -	11.40	6.73	78.23	1.74	1.90	1985
1772	Corn, - - - - - -	12.46	5.67	78.46	1.60	1.81	1960

* These include hay from mixed grasses as well as rowen from mixed grasses.

TABLE 74.—*(Concluded.)*

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Seeds.	%	%	%	%	%	Cal.
1773	Corn, - - - - - -	10.91	5.56	80.62	1.26	1.65	1965
1774	Corn, - - - - - -	10.96	6.55	78.94	1.54	2.01	1975
1775	Corn, - - - - - -	12.04	6.36	78.34	1.30	1.96	1975
	Average (20), - - -	**10.57**	**5.97**	**80.11**	**1.57**	**1.78**	**1965**
	Average all analyses (173),	**11.08**	**5.75**	**79.78**	**1.65**	**1.74**	**1965**
1706	Oats, - - - - - -	14.85	6.55	68.13	7.23	3.24	1955
1707	Oats, - - - - - -	12.31	6.46	68.97	8.67	3.59	1945
1708	Oats, - - - - - -	12.67	6.27	68.58	9.12	3.36	1945
1709	Oats, - - - - - -	12.74	6.36	70.56	7.32	3.02	1950
1710	Oats, - - - - - -	14.12	6.52	68.77	7.61	2.98	1955
1711	Oats, - - - - - -	12.02	6.45	71.03	7.48	3.02	1955
1712	Oats, - - - - - -	11.89	6.04	69.29	9.78	3.00	1945
1713	Oats, - - - - - -	12.07	5.97	69.03	9.78	3.15	1940
1714	Oats, - - - - - -	12.79	6.17	70.83	7.26	2.95	1950
1715	Oats, - - - - - -	13.17	6.34	68.81	8.51	3.17	1950
1716	Oats, - - - - - -	12.90	6.26	67.97	9.40	3.47	1945
1717	Oats, - - - - - -	13.13	5.90	67.91	9.77	3.29	1940
	Average (12), - - -	**12.89**	**6.27**	**69.16**	**8.49**	**3.19**	**1950**
	Average all analyses (50),	**14.61**	**5.97**	**66.52**	**9.76**	**3.14**	**1945**
	Milling and By-Products.						
1588	Corn meal, - - - -	10.44	6.20	79.53	2.03	1.80	1970
1598	Corn meal, - - - -	12.08	6.07	78.12	2.08	1.65	1975
1620	Corn meal, - - - -	11.38	5.10	79.30	2.47	1.75	1950
	Average (3), - - -	**11.30**	**5.79**	**78.99**	**2.19**	**1.73**	**1965**
	Average all analyses (23),	**11.07**	**5.19**	**80.26**	**1.81**	**1.67**	**1950**
1615	Buffalo gluten feed, - -	29.15	5.72	57.25	6.03	1.85	1960
	Average all analyses (6), -	**24.71**	**13.13**	**54.31**	**6.63**	**1.22**	**2145**
1594	Chicago gluten meal, - -	36.51	8.55	49.79	4.35	.80	2045
1614	Chicago gluten meal, - -	46.93	5.74	43.93	2.40	1.00	1980
	Average (2), - - -	**41.72**	**7.15**	**46.86**	**3.37**	**.90**	**2015**
	Average all analyses (7), -	**38.83**	**6.91**	**50.25**	**2.98**	**1.03**	**2005**
1616	Linseed oil meal, - -	41.78	7.33	35.79	9.38	5.72	1925
	Average all analyses (10),	**37.69**	**5.86**	**41.75**	**8.46**	**6.24**	**1885**
1590	Wheat bran, - - -	19.72	5.45	60.17	8.44	6.22	1875
1595	Wheat bran, - - -	19.05	4.97	60.10	9.97	5.91	1870
1597	Wheat bran, - - -	19.52	6.16	58.70	9.91	5.71	1900
1603	Wheat bran, winter, - -	19.28	4.69	59.64	9.54	6.85	1845
1604	Wheat bran, spring, - -	18.77	6.05	59.14	10.36	5.68	1900
1619	Wheat bran, - - -	19.37	5.01	61.56	8.55	5.51	1875
1643	Wheat bran, coarse, - -	16.41	5.85	59.26	11.96	6.52	1875
	Average (7), - - -	**18.87**	**5.45**	**59.80**	**9.82**	**6.06**	**1875**
	Average all analyses (38),	**19.01**	**5.60**	**59.25**	**10.02**	**6.12**	**1880**
1589	Wheat middlings, - -	18.87	4.40	70.93	3.09	2.71	1915
1601	Wheat middlings, winter, -	19.99	4.22	66.35	5.84	3.60	1890
1602	Wheat middlings, spring, -	22.48	6.22	58.90	7.43	4.97	1915
1644	Wheat middlings, - -	20.41	6.32	57.37	10.48	5.42	1905
	Average (4), - - -	**20.44**	**5.29**	**63.39**	**6.71**	**4.17**	**1905**
	Average all analyses (16),	**20.45**	**5.66**	**62.85**	**6.61**	**4.43**	**1910**

METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.

The meteorological observations made at the Station during 1896 have been similar to those of past years. The Station equipment consists of the ordinary instruments for observing temperatures, pressures of the air, humidity, rainfall and snowfall, uniform with those used by voluntary observers for the United States Weather Service. In addition to the records made at Storrs, the rainfall for the growing season has been recorded by quite a number of farmers in coöperation with the Station.

The total precipitation for the year (40.6 inches), as measured at Storrs, was considerably below the average yearly rainfall for this State. The average for Connecticut from observers having records covering more than five years prior to 1896, as given by the New England Meteorological Society, is 48.5 inches. The average at Storrs for the past eight years is 44.2 inches, and the average from fifteen observers of the New England Meteorological Society in the State having records covering the five years prior to 1896 is 44.7 inches. The rainfall was unusually large during the months of February and March, while April, May, and June gave an unusually small amount of rainfall. The rainfall throughout the remainder of the growing season was sufficient to keep up a fair growth of nearly all crops. The drouth early in the season was sufficiently severe to check the growth of grass and some garden crops, the hay crop being quite light.

The temperature for January was much below the average, while February and March were about normal. The spring opened quite early, April and May being mild and favorable for farm work. The last damaging frosts in the spring occurred on the 1st and 2d of May. The summer season was notable for several periods of extremely high temperature. Most farm crops except hay made a very fair growth. A light

frost occurred September 20th, and the first killing frost on September 24th, thus giving a growing period of 144 days after the last severe frost in the spring. The average growing season at this Station for the past eight years has been 145 days. The fall months were unusually wet, and unfavorable for harvesting corn.

Through the kindness of the New England Meteorological Society we are able to publish the rainfall records from twelve of their Stations in Connecticut.

Table 75 gives the rainfall as recorded for the six months ending October 31st for twenty localities in the State, and table 76 gives the summary of observations made by the Station at Storrs.

TABLE 75.

Rainfall during six months ending October 31, 1896.

Locality.	Observer.	Inches per Month.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village,	M. H. Dean,	3.39	2.53	6.67	4.25	6.25	3.10	26.19
Norwalk,	G. C. Comstock,*	5.33	4.26	4.71	2.53	5.42	2.22	24.47
Bridgeport,	Wm. Jennings,*	4.81	3.88	3.45	2.19	5.40	2.45	22.18
Waterbury,	N. J. Welton,*	2.34	5.71	3.16	2.67	5.01	2.77	21.66
Canton,	G. J. Case,*	2.93	3.80	3.39	4.12	6.58	3.73	24.55
West Simsbury,	S. T. Stockwell,*	2.86	3.63	4.57	3.02	5.96	3.16	23.20
Southington,	Lumen Andrews,*	2.91	5.30	3.23	3.20	6.13	3.30	24.07
New Haven,	Weather Bureau,*	3.67	2.96	3.86	2.57	3.42	2.91	19.39
Newington,	J. S. Kirkham,	2.62	5.41	2.39	3.04	2.85	3.85	20.16
Hartford,	Prof. S. Hart,*	2.51	4.63	2.40	4.84	—	3.65	—
Vernon Centre,	E. H. Lathrop,	2.15	4.26	3.61	3.24	4.15	4.54	21.95
South Manchester,	K. B. Loomis,	2.40	3.43	2.85	3.54	5.21	4.00	21.43
Middletown,	C. W. Hubbard,*	3.00	4.36	2.72	2.59	5.26	4.31	22.24
Madison,	J. D. Kelsey,	4.09	3.25	4.35	3.37	5.34	3.57	23.97
New London,	Weather Bureau,*	2.17	1.72	3.64	3.60	2.49	3.37	16.99
Colchester,	S. P. Willard,*	4.97	3.00	2.45	4.05	6.60	4.65	25.72
Lebanon,	E. A. Hoxie,	4.49	3.48	2.26	6.86	6.26	—	—
North Franklin,	C. H. Lathrop,	5.52	2.29	1.59	3.70	4.58	3.62	21.30
Storrs,	Experiment Station,	2.72	1.78	3.22	2.71	7.03	3.60	21.06
Voluntown,	Rev. C. Dewhurst,*	2.39	2.47	3.89	2.77	6.25	3.05	20.82
Average,	- - - -	**3.35**	**3.60**	**3.42**	**3.44**	**5.22**	**3.47**	**22.30**

* New England Meteorological Society Observer.

TABLE 76.

Meteorological Summary for 1896.

OBSERVATIONS MADE AT STORRS BY THE STATION.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, - -	30.52	30.48	30.56	30.53	30.37	30.35	30.34	30.33	30.38	30.57	30.81	30.90	30.51	—
Lowest barometer, - -	29.67	28.82	29.13	29.60	29.67	29.56	29.65	29.75	29.66	29.54	29.63	29.52	29.60	—
Mean barometer, - - -	30.17	29.87	29.91	30.10	30.02	29.99	30.03	30.03	30.05	30.04	30.19	30.14	29.96	—
Highest temperature, - -	40.5	52.8	57.0	84.8	89.8	86.6	88.9	91.3	87.4	73.6	69.0	54.2	73.0	—
Lowest temperature, - -	—13.0	—13.3	5.5	23.2	31.1	40.9	51.6	44.0	34.0	24.8	16.8	—3.0	20.2	—
Mean temperature, - -	21.8	26.3	28.5	47.5	59.9	63.2	69.6	68.5	59.9	47.2	43.5	26.8	46.9	—
Relative humidity, - -	—	—	—	68.2	67.2	75.1	79.8	77.0	80.3	77.0	—	—	—	—
Total precipitation, - -	1.60	7.10	4.86	.80	2.72	1.78	3.22	2.71	7.03	3.60	2.49	2.67	—	40.58
Number of days with precipitation of .01 inch or more,	7	10	11	3	9	7	10	9	8	10	7	6	—	97
Number of clear days, - -	9	6	12	13	9	9	8	13	8	7	6	12	—	112
Number of fair days, - -	12	13	10	15	14	12	12	10	7	8	12	9	—	134
Number of cloudy days, -	10	10	9	2	8	9	11	8	15	16	12	10	—	120
Total movement of wind in miles,	6863	9741	11805	6955	6253	5659	5339	4407	5959	6476	6205	7333	—	—
Maximum velocity of wind, -	48	54	60	36	45	30	28	25	42	42	35	60	—	—

INDEX.